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DERMOID CYSTS AND TERATOMATA OF THE MEDIASTINUM

A REVIEW

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"IT WOULD be difficult to find in the adult human body a region of less intrinsic interest than that space between spaces known to anatomists as the anterior mediastinum." Thus spoke J. C. Wilson of Philadelphia at the beginning of a lecture on the differential diagnosis of mediastinal tumours in 1884. However unpretentious this "space between spaces" may appear to the anatomist, it does not lack appeal to the clinician and pathologist for one group of tumours found therein, the dermoid cyst and its more complex blood relation the teratoma, has provided for more than a century a fascinating field for speculation and study. Such tumours are found uncommonly in this situation; an estimate of their rarity can be formed from the publication of Hare (1889), who collected from the literature 500 cases of mediastinal disease of which only 10 were tumours of this type. Moir (1936) has stated that only two examples were among the patients admitted to the general medical wards of the Leeds Infirmary over a period of ten years, while at the London Chest Hospital, which draws its material from all over the country, five cases have been seen in seven years. Although rare, they are not unimportant both with regard to the manifestations to which they give rise and to the treatment that they require.

HISTORICAL SURVEY

The first example of a tumour of this type to be recorded, a dermoid cyst of the mediastinum, was made the subject of an address to the Medico-Chirurgical Society of London on Nov. 25, 1823, by J. A. Gordon,

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and subsequently published by him in the Transactions of the Society in 1827. It concerned a young woman, aged 21 years, seen at the Islington Dispensary, where the diagnosis of pneumonia was made. The illness pursued an atypical course for, despite repeated blood letting, she was left with an irritating cough and a persistent tachycardia of 120 beats per minute. The appearance, later, of a small pulsating tumour beneath the sternal end of the left clavicle caused a revision of the diagnosis in favour of an aneurysm of the aorta or innominate artery. This swelling increased in size and burst to discharge a serous fluid. The girl died shortly afterward and a limited autopsy disclosed an adherent tumour of the anterior mediastinum containing sebaceous matter and hair. At one end of the cyst was a plaque of bone that bore a striking resemblance to the superior maxilla and to which seven teeth were attached.

Spath (1836) reported a large tumour of the anterior mediastinum extending into the neck. It was discovered post mortem and was composed of fibrous and fatty tissues, bone, and cartilage, but no microscopic study of the specimen was undertaken. Three years later, Munz (1839) published a detailed clinical account of a dermoid cyst in a woman of 28 years who had suffered all her life from catarrhal affections and who had noticed hairs in her phlegm since she was 15 years old. She became phthisical and died, the coexistence of pulmonary tuberculosis and a dermoid cyst being confirmed at autopsy. This case is quoted by Godlee (1889).

In succession to Büchner's case in 1853, sporadic examples were reported by later writers (Lebert, 1858; Cordes, 1859; Cloetta, 1861; Salomonsen, 1864; Collenberg, 1869) until 1869 when the condition was clearly recognised as a clinical entity, for in that year Nobiling showed a preparation of a cyst that had been correctly diagnosed during life, owing to the expectoration of hairs. In the remaining years of the nineteenth century, thirty-five additional cases were recorded, serving mainly to enrich knowledge of the pathology of the condition and to emphasise the difficulty in reaching an accurate diagnosis of the condition during life and before operation. Reviews of the subject during this period were presented by Hare (1889), Dardignac (1894), Pflanz (1896), and Ekehorn (1898).

Dangschat, in 1903, collected forty-two examples from the literature and added two of his own, while two years later Morris (1905) placed the total number of cases on record at fifty-nine; these included a patient that he had himself observed and who had been operated upon by Senn (1905). Morris, however, omitted one or two references that have come to light from other sources and included one case (Fletcher, 1897) of a congenital cyst arising in connexion with the foetal oesophagus that should be classed separately.

Hertzler (1916) published an exhaustive review of the literature up to that time which comprised seventy-two case reports, and Lambert and Knox, in 1920, reported six cases. Of these only one was a proved teratoma but four others are sufficiently suggestive on clinical grounds to be accepted as genuine examples of this condition, while one case with a syphilitic history, a doubtfully positive Wassermann reaction, and a posteriorly placed tumour cannot justifiably be included.

Kerr and Warfield, in 1928, computed the total number of recorded cases at 138, but a study of the original case reports has raised a doubt as to whether some of these are, in reality, genuine examples of intrathoracic dermoid cysts or teratomata. For instance, the cases published by Clutton (1887) and Selby (1906) would seem to resemble presternal dermoids having no connexion at all with the mediastinum. Again, a reading of Fawcett's (1906) original account of a woman, aged 62 years, whose symptoms had been of short duration and were correlated with physical signs pointing to bronchial obstruction strongly suggests, in the light of the post-mortem findings and in the absence of microscopic proof to the contrary, a diagnosis of a breaking-down carcinoma of the right lower lobe bronchus with secondary deposits in the mediastinal glands. Other examples could be quoted. Since Kerr and Warfield's article appeared, ninety well-authenticated cases of this condition were published up to the end of 1939. It is unprofitable at this time to pursue the detailed study of the literature much beyond the outbreak of the present war in view of the difficulty of obtaining access to continental literature. As far as possible the original source has been consulted for information or an abstract of it obtained, but this has not always been possible. After allowance has been made for those examples, included by other workers, which cannot be accepted on the evidence presented and excluding the six cases described for the first time in this communication, it has been possible to trace in the literature up to the end of 1939, 245 recorded cases of intrathoracic dermoid cysts and teratomata. It is upon practically the whole of this material that the following review is founded.

CASE REPORTS

CASE 1.—E. S. was a married woman, aged 42 years. Her past medical history had been uneventful and free from major chest affections, but she had noticed that for some years she had been unduly short of breath on effort and subject to attacks of palpitation. No more tangible symptoms than these became manifest, however, until towards the close of 1937, when she began to experience an intermittent pain in the centre of the chest about the level of the second rib which spread across to the left side. It was sharp in character and although spasmodic did not resemble a true anginal pain on effort. One week later she became aware of a small pulsating tumour in the neighbourhood of the second left rib a short distance from the sternum, and it

was on account of this that she attended her local hospital. Physical examination suggested an aneurysm of the thoracic aorta and an x-ray picture showed a well-defined "tumour" in the centre of the chest that abutted slightly into both the right and left lung fields. The Wassermann reaction was negative.

She was confined to bed for three months and the symptoms improved; for a further eight months good progress was maintained. At the end of that time, however, she complained of pain across the shoulders and up and down the neck and noticed that her "heart was thumping a lot." She also developed a dry, croupy cough that was worse at night. She was seen by Dr. T. W. Preston who was not satisfied with the previous diagnosis and referred her to the London Chest Hospital for further investigation. At the time of her admission she suffered from a dragging pain in the left side of her chest, a short, dry, wheezy cough, often noisy and provoked by lying back, noticeable pulsation in the chest, shortness of breath on walking, and some recent loss of energy. There had been no voice change.

Physical Examination.—The most striking feature was the pulsation, which was of sufficient force to shake the whole body. Complexion was unhealthy but general bodily condition was good. There was an irritating dry cough that at times possessed the "gander" quality traditionally associated with aneurysm of the aorta. She always sat up in bed, knowing that to lie back would be to invite a fit of coughing.

The heart's impulse was forceful and the apex beat located in the sixth interspace one-half inch outside the midclavicular line. There was a localised area of pulsation in the second left interspace two and one-half inches from the midsternal line; over this area the percussion note was impaired and a systolic bruit heard. There was unmistakable tracheal tugging. Blood pressure was 135/85 mm. Hg and approximately equal in both arms.

The left side of the chest was slightly fuller in its upper part than the right and in movement lagged behind its fellow. Air entry into the left apex was poor. There were no other abnormal physical signs in the chest.

The pupils were regular with a moderate aperture and reacted briskly to light and convergence. All tendon jerks were normal. No other significant feature was found.

Radiography.—An anteroposterior picture of the chest (Fig. 1) showed that the tumour had increased in size since the previous film was taken a year before. The shape and clear-cut edge, however, remained the same. A left lateral picture (Fig. 2) disclosed the position of the tumour in the anterior mediastinum beneath the sternum. Fluoroscopic screening demonstrated the vigorous pulsation of the mass. The aorta was investigated in more detail; the transverse arch and descending thoracic aorta could be visualised with ease and there was no widening

or any other detectable abnormality in this portion of the vessel. It was not possible, however, to make out the first part of the ascending aorta, and no opinion could be formed as to whether it was healthy or diseased. A series of tomographic pictures was unhelpful.

Other Investigations.—Wassermann reaction was negative before and after a provocative dose of novarsenobillon. Electrocardiograph showed a normal rhythm with a right axis deviation. Friedman test, Casoni reaction, and complement fixation test for hydatid disease were all negative. There was no abnormality in the urine. Blood count: red cells

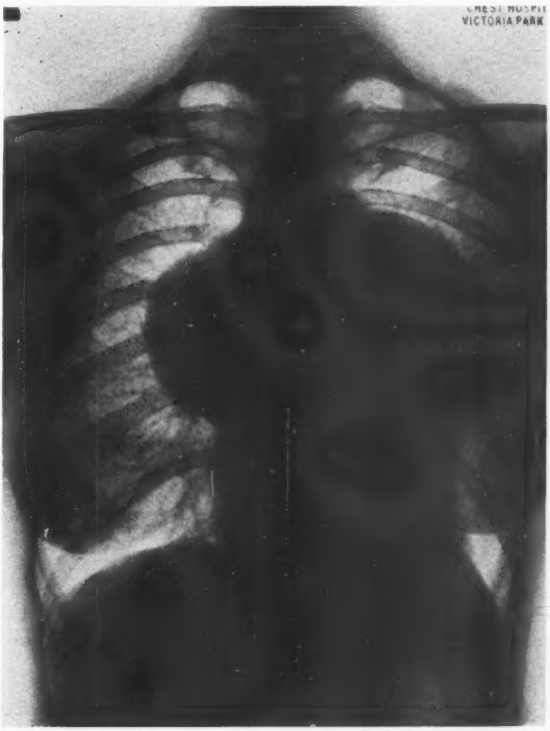

Fig. 1.—Case 1 (E. S.). Anteroposterior skiagram of the chest.

4,700,000 per c.mm. with 92 per cent haemoglobin, leucocytes 15,000 per c.mm.; blood sedimentation rate 24 mm. in the first hour (normal from 3 to 7). The slightly raised leucocyte count and the elevated sedimentation rate suggested the presence of infection. There was no fever but a sustained tachycardia of 100 to 120 beats per minute and a respiration rate of 22 to 25 per minute were abnormal features.

An accurate clinical diagnosis was not easy; a saccular aneurysm of the ascending aorta or a benign tumour of the mediastinum, probably

a dermoid cyst, seemed the most likely possibilities. The real difficulty sometimes encountered in making a distinction between these two, at first sight apparently clear cut, conditions will be discussed more freely later. It seemed that in this instance a benign tumour of the mediastinum transmitting pulsation was the more likely of the two alternatives and, as the tumour was embarrassing the patient and threatened her life in the near future if its steady growth was maintained, an exploratory thoracotomy was advised and accepted.

Fig. 2.—Case 1 (E. S.) A left lateral x-ray picture; the tumour occupied the anterior compartment of the mediastinum beneath the sternum.

Operation.—An artificial pneumothorax was induced on the left side as a preliminary to operation. The lung collapsed well, the localised area of pulsation became less apparent, and the percussion note over it resonant. The operation was undertaken under light gas and oxygen anaesthesia, but the patient died suddenly after the skin incision had been made and before the chest had been opened.

Autopsy.—A very large tumour was exposed as soon as the sternum was removed. It completely covered the heart and was adherent to the

right and the left lung and, higher up still, to the trachea. It was impossible to separate the tumour from neighbouring structures and the thoracic viscera were removed with it.

The tumour comprised one large cavity filled with thick, yellow, greasy, sebaceous material containing many hairs. To the apex of the heart was attached a small daughter cyst, unconnected with the parent cavity but containing similar sebaceous material lacking hairs. The specimen is shown in Fig. 3. It was opened and as much of the contents as possible removed, but flakes of the yellow material clung to the posterior wall and to the hairs. The daughter cyst is shown below

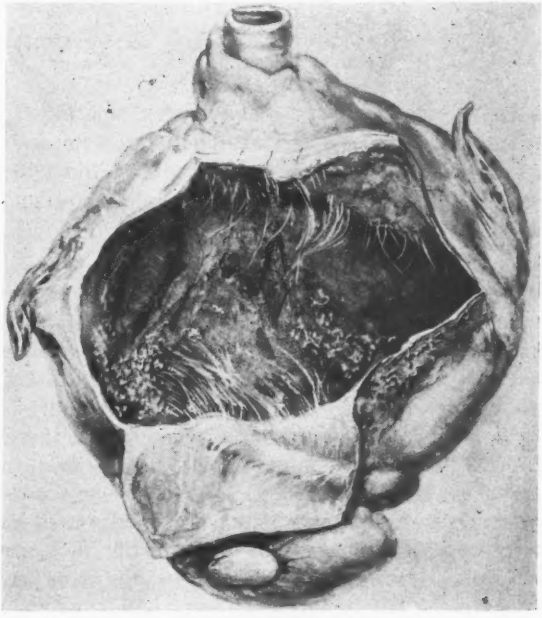

Fig. 3.—Case 1 (E. S.). Specimen removed at autopsy showing the dermoid cyst (opened) lying in front of the heart. The trachea is seen above, tags of lung at either side with the heart's apex, with small daughter cyst attached, below. (A photograph of a coloured drawing made by W. Thornton Shiells.)

on the heart's apex and tags of lung tissue, firmly bound to the cyst, can be seen on either side. The wall of the cyst was moderately thick and uniform in contour except in the anterior portion along which a ridge ran from left to right and downwards across the surface; it was from this ridge, and only from this ridge, that the hairs sprang.

A remarkable feature of the cyst was its firm union to the pericardium. A careful dissection of the tumour and surrounding structures was made, but it was impossible to find a line of natural cleavage between the posterior wall and the pericardium. This is very likely significant in

explaining the persistent tachycardia, the unusual degree of pulsation, and the right axis deviation in the electrocardiograph, as the right ventricle was the chamber that bore the brunt of the additional burden, and contributed, perhaps, to the sudden and unexpected death of the patient.

Microscopy.—The wall of the cyst was composed of broad strands of fibrous tissue and some area of smooth muscle could be made out. The inner lining consisted of stratified squamous epithelium with flaky epidermis attached to it. Immediately beneath the surface, sebaceous glands could be seen in profusion together with their ducts, while deeper in the section were found many fat spaces and one or two plaques of cartilage.

The structure of this cyst proved it to be a teratoma of the dermoid type.

CASE 2.—D. W., aged 34 years, was a married woman. She had had no major illnesses in the past and no liability to catarrhal affections. She married a soldier and accompanied him to Egypt in 1931, where she stayed for two years. During this period she had an attack of dysentery of moderate severity for which treatment by injections was not advocated. Her husband's regiment was transferred to India, and she went with him and remained there for four years.

It was towards the close of her visit to India, in June, 1937, that the patient experienced the first symptoms referable to her present malady. These were pain in her chest and shortness of breath. The pain was felt in front of the chest and towards the left side and was provoked by taking a deep breath, by coughing, and laughing. It was sharp in character and, although intermittent, the patient was conscious of there being "always something there." At the same time she became aware of shortness of breath on walking, which impressed her as being unusual even when allowance was made for the fact that she was resident at a hill station. Five months later, the pain became worse and for ten days she felt it under the left armpit and remarked that it travelled down the inner side of the left arm to the fingers. Although there was no loss of power in the left arm she wanted to rest it all the time. Her general health was not good and she lacked energy.

She returned home from India in December, 1937, and on the journey had three haemoptyses consisting of bright blood mixed with a little sputum. Apart from this, there was little change in her symptoms until February, 1938, when a dry "tickling" cough became noticeable and further haemoptyses occurred. An x-ray picture was taken of her chest, blood tests were carried out, and the sputum was repeatedly examined for tubercle bacilli but none was found. Lassitude became more striking and the cough persistent, accompanied by a little mucoid sputum, until April, 1938, when she was admitted to a Military Hospital

with an attack of "acute bronchitis." She had a temperature up to 102° F., cough and sputum increased, and the phlegm became thicker and resembled "anchovy sauce," according to her doctor. The sputum was not greasy and contained neither particles nor hairs. The illness lasted fourteen days and then abated but residual symptoms remained. The patient was transferred to the London Chest Hospital under the care of Dr. H. V. Morlock in December, 1938, for further investigation with a provisional diagnosis of an aneurysm of the aorta or pulmonary artery.

On admission to the hospital she suffered from a persistent cough productive of scanty mucoid sputum. The phlegm was never purulent and no particles or hairs were seen in it. There had been no haemoptysis for eight months. The pain in the chest of which she had complained for the past eighteen months was still present and associated with palpitations, especially when she became excited. Her breath was short when she climbed stairs and during bouts of palpitation.

Physical Examination.—The patient was a well-nourished woman with a normal temperature, pulse, and respiration rate. She lay comfortably in bed.

Movement of the left side of her chest was defective and the percussion note impaired over the anterior and upper part and a few crepitations were audible near the left edge of the sternum. There was no clubbing of the fingers.

A visible and palpable area of pulsation could be observed over the second and third left interspaces, but in all other respects the cardiovascular system was normal, the heart sounds were clear and precise, and the position of the apex beat was not displaced. The blood pressure was 115/80 and equal in the two arms. No tracheal tugging could be detected and the pupils were equal and regular, reacting normally to light and convergence. No enlarged glands were palpable and the other systems of the body presented no unusual features.

Radiology.—An anteroposterior and a left lateral x-ray picture showed a moderate-sized tumour abutting towards the left side and lying in the anterior mediastinum. The tumour possessed a clear-cut outline and the aortic knuckle could be easily identified (Figs. 4 and 5). A screening examination combined with a kymograph showed that the mass pulsated but was unconnected with the aorta and it was therefore concluded that this pulsation was transmitted rather then inherent.

Other Investigations.—The Wassermann reaction and the Kahn test of the blood were both negative.

The red blood cells numbered 5,500,000 per c.mm. with 94 per cent of haemoglobin; the white cells were 11,500 per c.mm. with a normal differential and no eosinophils. The blood sedimentation rate was normal.

The sputum contained a mixed flora, but tubercle bacilli and spirochaetes were absent from it.

Bronchoscopy supplied no helpful information.

An artificial pneumothorax was induced on the left side and the tumour inspected with a thoracoscope. It was rounded with a smooth wall and lay above and in front of the heart, pulsating freely with it. It had a cystic appearance.

The possibility of mediastinal hydatid cyst was considered and much interest was aroused when the Casoni test proved to be positive, but the hydatid complement fixation test, which was carried out later, was negative.

Fig. 4.—Case 2 (D. W.). Anteroposterior skiagram showing the tumour abutting toward the left side.

The evidence, therefore, pointed to a benign tumour of the mediastinum probably of the dermoid type, and a thoracotomy was advised and accepted by the patient.

Operation.—Operation was undertaken after the pneumothorax had re-expanded, and was performed by Mr. T. Holmes Sellors with an anterior approach under gas and oxygen anaesthesia.

The chest was entered through an intercostal incision; the divided sternal ends of the second and third ribs were retracted upwards and

the fourth downwards. The tumour then came into view. The pleural capsule was incised and the tumour separated from the left lung and pericardium to both of which it was firmly united. Some difficulty was experienced in freeing it from the posteromedial attachment, especially at its upper pole which lay to the right of the midline, and an indefinite pedicle was seen. In the course of this manipulation the cyst wall was punctured and a white semisolid structure, the size of a thumbnail, herniated through the opening. To this some hairs were attached. The tumour was removed completely and the chest repaired without drainage.

Fig. 5.—Case 2 (D. W.). A lateral picture, same case as Fig. 4.

The postoperative progress of the patient was fairly smooth. A blood transfusion was given shortly after the operation and on four occasions in the ensuing week some bloodstained fluid was aspirated from the left chest. No empyema developed and a thin trickle of serous discharge continued for some weeks from the sternal end of the wound, but this dried up and she was discharged perfectly well two months after operation.

The tumour was a multilocular cyst with thin walls containing a viscid, transparent, gelatinous fluid. There was a central core of warty consistence with one long hair and numerous short ones growing from it.

Microscopy.—The warty central core was made up of fibrous and fatty tissue and covered by squamous epithelium. Sebaceous glands could be seen deeper in the section and some of the ducts into which they drained could be picked out. The walls of the loculations were of similar structure. In one area some tissue closely resembling salivary gland tissue was identified.

This tumour, like the preceding example, could be classified as a teratoma of the dermoid type and exhibited, histologically, similar characteristics to many such cysts recorded in the literature.

Case 3.—Mrs. Y., aged 25 years, was a patient under the care of the late Dr. A. J. Scott Pinchin. Her health, until 1934, had been unremarkable except for a tendency to catch cold, which "colds" always descended to her chest. In 1934, she had a more severe respiratory infection than usual during the course of which a heart murmur was noticed and she subsequently experienced breathlessness on going up stairs or when hurrying. A skiagram, taken early in 1935, revealed an abnormal shadow. Towards the end of that year the patient had a series of attacks of pain in the upper part of the left side of the chest associated with a temperature up to 100° F., much shortness of breath, and vomiting. She experienced three such attacks, each lasting about one hour. There were bouts of fever in between these attacks but little coughing, and her weight was steady.

She was well nourished and displayed few physical signs on examination of her chest. A radiologic investigation, however, disclosed a rounded mass with a well-defined edge lying in the anterior compartment of the mediastinum. The appearance of the tumour in the antero-posterior view is shown in Fig. 6; the lateral is not reproduced.

She was kept under observation for six months and during this period her symptoms increased in severity and the tumour in size, and she developed an effusion at the left base. The diagnosis of probable dermoid cyst was made and exploratory thoracotomy advised and accepted.

The operation was performed by Mr. T. Holmes Sellors, through an anterior incision, and adequate exposure of the mediastinum was obtained by resection of short lengths of the second and third ribs on the left side. An oval cyst, measuring about three and one-half inches in diameter, was seen lying in the anterior mediastinum. It was adherent to mediastinum and chest wall and, although it proved possible partially to free the cyst, its complete removal could not be effected in view of the firmness of the adhesion to the pericardium and aortic arch. Five-sixths of the tumour, however, was excised and sufficient

mobilisation of the remainder was accomplished to enable it to be drawn up to the original incision and marsupialised to it. The fluid content of the cyst, which escaped under pressure, was the oily, sebaceous matter characteristic of the condition and contained hairs and cholesterin crystals.

Fig. 6.—Case 3 (Mrs. Y.). Anteroposterior skiagram to show the size and shape of the tumour.

The patient's recovery from the operation was uneventful and all symptoms were relieved. There remained, however, a persistent sinus and a small amount of discharge. Despite this disability she gave birth to a male child whom she fed at the breast. Some months later, the sinus was treated with pure carbolic and formalin following which it closed and has remained sealed. This patient, when seen and examined six years after operation, was well with no symptoms, the sinus remained firm, and the x-ray picture showed little departure from the normal except for elevation of the left dome of the diaphragm due to interruption of the phrenic nerve at the time of operation.

This case, which again exemplifies the tendency of the dermoid cyst to enlarge and so cause symptoms early in adult life, is an excellent

illustration of the success that may result from partial removal and marsupialisation if total extirpation is prevented by firm union of the tumour with neighbouring structures.

CASE 4.—W. B. was a man, aged 33 years. He gave no history of any pulmonary disorder nor was he complaining, at the time he was examined, of any symptoms referable to the respiratory tract. One

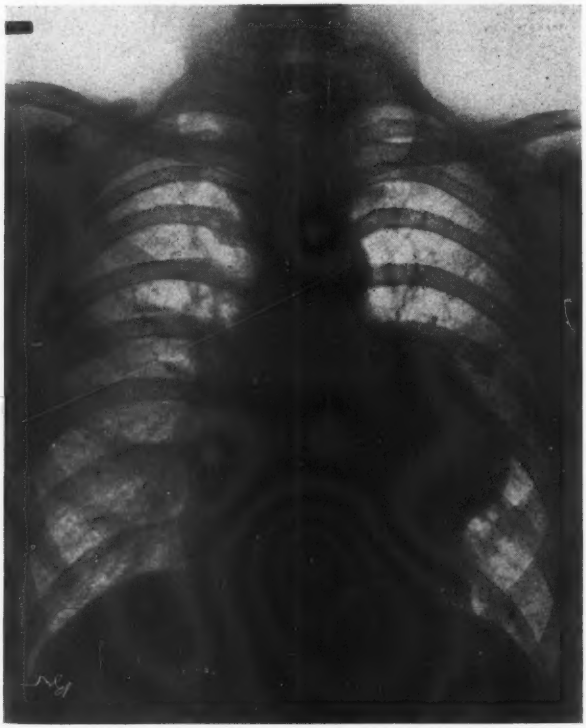

Fig. 7.—Case 4 (L. B.). Anteroposterior skiagram of a tumour of the left side, presumed to be a dermoid cyst.

brother had recently contracted pulmonary tuberculosis and another had died of the disease a few years before, and it was in response to a request from Dr. J. E. Stokes, the Tuberculosis Officer of his district, that he attended the Dispensary as a "contact." A routine screening of his chest was performed and an unusual shadow seen. He was referred to Dr. W. Burton Wood's outpatient clinic at the London Chest Hospital for a more detailed investigation. This was in 1937.

He was a thin man of average build and his general physical condition was good. He confessed to no pulmonary symptoms and the only abnormal physical signs that could be detected were some impairment of the percussion note in front in the upper half of the left side of

the chest and an area of localised pulsation in the third left intercostal space, one and one-half to two inches from the edge of the sternum.

The radiographic appearance of the chest in anteroposterior and left lateral view is depicted in Figs. 7 and 8. These films show a rounded shadow with a clearly defined edge apparently arising from the mediastinum and encroaching upon the left lung. It was anterior in position. On the screen it was separate from both the aorta and pulmonary artery as far as could be determined, and it pulsated.

Fig. 8.—Case 4 (L. B.). Lateral view, same case as Fig. 7. The tumour is seen to lie in the anterior mediastinum.

The Wassermann reaction of the blood was twice negative, as was the Friedman test.

The patient was re-examined some months later when further x-ray pictures were taken. There had been no increase in the size of the tumour in that period.

He was encouraged to attend the outpatient department at regular intervals in order that a watch might be kept upon his progress, but his visits were only sporadic and later ceased entirely. All further attempts to get in touch with him were unsuccessful until December, 1939, when he was traced and persuaded to submit to another x-ray picture. The

appearance of the tumour then, two years after the discovery of the disease, was similar in every respect to that previously noted and no increase in its size was detectable. At this examination, however, the impression was formed that the pulsation in the third left interspace was more obvious than it had been a year before.

The patient's mentality was of a low order and his reaction to a discussion as to the nature of his illness and what could be achieved and possibly prevented by surgery was unhelpful. For this reason and because of the symptomless character and stationary size of the tumour, an exploratory thoracotomy was not pressed.

It is evident that the diagnosis in this instance is as yet unproved. That it is a benign tumour seems reasonably assured in view of the absence of symptoms and a failure to grow over a span of many months, while the position of the tumour in the chest and the sharply defined contour of the mass seen in the x-ray picture suggest, in conjunction with other proved examples that have been observed or studied in the literature, a teratoma of the dermoid type.

Case 5.—W. D., a man, aged 27 years, was admitted to the London Chest Hospital under the care of Dr. H. V. Morlock for investigation and treatment.

There had been no history pointing to chest disease until three years before, when he had an attack of pneumonia that left him with a residual cough culminating in an haemoptysis six months before admission. The blood was moderate in amount and dark in colour. The cough became productive of an offensive, purulent sputum, particularly in the morning. The sputum was negative for tubercle bacilli. Four months previously he had become more seriously ill. The cough and sputum increased and caused him to vomit in the morning and he lost about two stones in weight.

At the time of his admission to the London Chest Hospital he was very ill with an irregular temperature up to 101° F., dyspnoea, and clubbing of the fingers. Physical examination disclosed signs in the left side of the chest consisting of restricted movement and impairment of percussion note from the clavicle downwards. Breath sounds were weak in front and absent at the left base posteriorly.

The sputum, which amounted to between three ounces and five ounces daily, was purulent and contained a variety of organisms including spirochaetes. In it were seen, also, numerous yellow granules that microscopic investigation showed to consist of clumps of acid-fast bacilli. This led to the sputum being reported first as positive for tubercle bacilli, but a more detailed study showed that these organisms were acid-fast but not alcohol-fast and if treated first with alcohol they lost there acid-fast properties.

At bronchoscopy a tumour was seen blocking the lumen of the left main bronchus and pus was pent up behind the obstruction. A

portion of the tumour was removed for microscopy and the section disclosed stratified epithelium from which processes were identified, dipping deeply down into the fibrocellular tissue beneath. The tissue was infiltrated with leucocytes.

A few days later the patient coughed up a portion of the tumour the size of a hazelnut and resembling a fibroma in appearance. This was followed by a severe haemorrhage and death ensued.

At autopsy the left pleural space was obliterated and the right sac contained some free fluid. A large cyst lay in the anterior mediastinum and extended into the left thoracic cavity. It was attached to the pericardium. In places the wall was composed of dense tissue three-fourths inch in thickness, while in other parts it was thinner. From the inside of the cyst were numerous papillomatous processes projecting into the cavity and some of these supported smaller papillomata. To these processes hairs were attached and the lining membrane was pitted, strongly resembling skin. A large quantity of sebaceous matter was present in the cyst.

The left lung was the seat of pneumonia with bronchiectasis at the base, while a terminal bronchopneumonia was present in the right lung. A communication was found between the cyst and the bronchial tree.

This case illustrates how an infected dermoid cyst may terminate fatally in a few months if surgical treatment is withheld in the early stages, and provides an example of pulmonary suppuration and bronchiectasis occurring secondary to pressure on the bronchus by the tumour and the aspiration of the infected contents of the cyst. It is also interesting from the bacteriological point of view, for no other case in the literature can be found in which examination of the sputum has revealed similar organisms to the acid-fast, nonalcohol-fast bacilli isolated in this instance.

CASE 6.—B. S., a little girl aged 1 year and 4 months, was never seen by a doctor until after her death. From the mother's statement there was little indication of respiratory disease and no suggestion of a recent failure of general health. There was, however, a history of "mild bronchitis" for a few weeks. Suddenly, early one morning, she had a convulsive seizure and died twenty minutes later before medical aid could reach her.

At autopsy a tumour of moderate size was found in the anterior mediastinum. It was mainly solid but contained numerous cystic spaces filled with grumous material and, in some areas, haemorrhagic exudate. The tumour surrounded the trachea and great vessels to all of which it was firmly attached while, a little lower down, it was firmly adherent to the pericardium. Dissection failed to free the tumour completely from its neighbouring mediastinal structures. No other abnormality was disclosed by the post-mortem examination and no secondary deposits were found.

Microscopic study was made from three sections cut from different portions of the tumour:

Section 1: A large part of the tissue in the first section was composed of apparently normal thymus gland, including Hassall's corpuscles, separated from the main mass of the tumour by a distinct barrier of fibrous tissue.

The tissue itself presented a glandular appearance with the cells irregularly arranged but with an attempt at acinous formation. It could best be described as adenocarcinomatous.

Section 2: The second section was composed predominantly of cystic spaces lined by cubical and high columnar epithelium. For the most part the epithelium constituted a single layer, but in a few places it was heaped up and ciliated. Between these two extremes a transitional stage could be made out indicating that the one was only a variant of the other. Many of these cells were goblet cells and obviously mucus-secreting.

An interesting feature of this section was the presence of undoubted salivary gland tissue, while, in addition, pigment could be seen which failed to take the stain for free iron, thereby suggesting that its origin was not haemorrhage but more likely melanin from the choroid.

Section 3: One plaque of cartilage was seen in this section and was found nowhere else. Cystic spaces similar to the foregoing were found and the adenocarcinomatous tissue, necrotic and haemorrhagic in parts, was present in abundance.

On this histological evidence there seems little doubt that the tumour was a mainly solid, partially cystic, teratoma that had undergone malignant, adenocarcinomatous degeneration and so brought about the death of the child.

PATHOLOGY

Although the origin of teratomata of the mediastinum is believed to result from faulty development occurring in embryonic life, it is well recognised that the majority lie dormant within the chest for many years and only become obtrusive when adolescence or early adult life is reached. This is borne out by a study of 174 cases in the literature in which is given the age at diagnosis. These cases can be grouped into decades as shown in Table I.

TABLE I

AGE (YEARS)	NO. OF CASES
0- 9	17
10-19	27
20-29	68
30-39	37
40-49	11
50-59	13
over 60	1
Total	174

The specimens found accidentally at autopsy on patients who died of an independent disease have not been included. There is no predilection for sex: out of 177 instances in which the sex is stated, 91 were found in females and 86 in males.

The position of these tumours in the chest is the anterior mediastinum, but they are generally found to encroach upon one or other side of the thorax. Even when they seem to have no apparent connexion with the mediastinum, a pedicle will sometimes be discovered stretching from the tumour to the centre of the chest. Neither side is favoured in this encroachment, for in 166 cases in which information is available, 88 abutted towards the right lung field, 65 inclined towards the left side, while 13 are given as central in position.

Pathologically the tumours exhibit the utmost variation and although it is possible to recognise two definite types—the simple dermoid cyst and the more complex teratoma—this division is not a rigid one. An apparently simple cyst will be found to contain tissue that unquestionably stamps it as a teratoma, while in other instances the main bulk of the tumour is simple and cystic, but at one pole is found a solid collection of tissue containing representation from all three germinal layers. It is convenient, therefore, to describe all these tumours as teratomata and to qualify the term according to the type of tumour. Thus, for purposes of description, they will be divided into teratomata of the dermoid type and the solid teratomata.

Teratoma of the Dermoid Type.—The dermoid is the simplest and the commonest type of teratoma found in the anterior mediastinum. It is generally composed of one single cystic cavity containing sebaceous material, but it may be bilocular or multilocular. In some cases accessory and smaller dermoids are found clustering around the parent cyst but having no connexion with the main tumour. Examples of this have been recorded by Carpenter (1906) and Harris (1919) and in the first case described in this communication a small daughter cyst, the size of a hazelnut, was attached to the heart's apex. It was filled with the same yellow sebaceous fluid as the main cyst but was quite distinct from it.

Macroscopically, the dermoid cyst may remain small and latent throughout life. On the other hand, it may attain a very large size, this tendency to grow usually becoming manifest in adolescence or early adult life and seems often to be provoked by an independent respiratory infection such as pneumonia or an attack of so-called influenza. The wall of the cyst on its outer surface is normally smooth and enclosed in a fibrous capsule, but it may be bossed. It is sometimes attached to the mediastinum or sternum by a pedicle of variable length and thickness that has to be ligated and divided if surgical treatment is to be successful. Apart from this pedicle it is common to find the cyst adherent to

surrounding intrathoracic structures such as the pericardium covering the heart and great vessels, the lungs and bronchi, the chest wall, sternum, mediastinum, and parietal pleura in approximately that order of frequency. These adhesions range from thin, tentative attachments that can easily be broken down by blunt dissection to a firm and intimate union requiring the knife or scissors for their release if, indeed, they can with safety be severed. From the inner lining of the cyst numerous fingerlike protuberances are often discovered jutting into the cavity, or a hard ridge is detected running the length of the tumour. This ridge may be partially made up of cartilage or bone, in some cases conforming to a well-known structure in the body such as the superior maxilla (Gordon, 1827). As a rule it is from these papillomatous processes or from this ridge that wisps or clumps of hair spring.

Microscopically, a dermoid cyst is a benign and relatively simple tumour although rarely it is found to have undergone malignant change. In the main the structure closely resembles that of skin, with an epithelial lining frequently of the squamous type, sebaceous and sweat glands present in large numbers, and hair follicles evident, together with smooth and striated muscle. Deposits of calcium and plaques of bone, cartilage, and teeth have been encountered on many occasions and a feature of many specimens is glial and nerve tissue and retinal pigment derived from the choroid (Whittemore, 1923 and Doran & Lester, 1939).

The epithelium of a dermoid cyst provides by its diversity a characteristic feature. It is not always of the stratified, squamous type but may be transitional in character, cubical and high columnar, with or without cilia. In some examples all kinds of epithelium have been present. Sometimes tissue derived from germinal layers other than ectoderm is apparent, such as salivary gland (Goebel and Ossig, 1912; Körner, 1918; and Kleinschmidt, 1920), pancreas with islets cells (Gordon, 1930; and Hablützel, 1933), thymus, thyroid, and intestine. It is this type of histological finding that bridges the gap between the dermoid cyst and the solid teratoma.

Solid Teratoma.—The solid form displays a difference from the dermoid cyst just described partly in its macroscopic and histological structure and partly in its potentiality for malignant change. A study of the tumours of this class that proved to be malignant shows that 70 per cent have arisen in the solid teratomata and 30 per cent in the teratomata of the dermoid type. The term solid teratoma is not an exact one, as many examples placed in this category are only partially solid and contain, in addition, multiple small cystic spaces filled with mucus and often containing blood. The naked eye appearance varies from a tumour that is difficult to distinguish from a teratoma of the dermoid type to a complex growth with an organised structure that deserves the name parasitic foetus (Harrington, 1932).

Microscopically, too, the tissue that comprises the more solid forms of teratomata, although derived from all of the three germinal layers,

exhibits a variable complexity that may be very simple or may reveal tissue representative of every organ of the body.

PATHOGENESIS

The mediastinal terato-dermoid tumour provides a perplexing aetiological problem for which there is even yet no satisfactory explanation.

In the earlier writings there is apparent a tendency to regard the dermoid cyst as a separate entity from the teratoma and Lebert (1858), who first suggested the division, looked upon the two types as distinct. It is very tempting to adopt this view and to postulate a separate aetiology for these two groups which apparently differ so widely in their pathologic features and malignant propensities. On this basis the dermoid cyst would be classed as an inclusion phenomenon occurring in a line of natural cleavage and, thus, would fall into line with cysts of similar structure found in other parts of the body. The evidence supporting this hypothesis can be summarised as follows:

1. The structure of the dermoid cyst, studied by previous workers, often conforms closely to that of the skin and its appendages and no embryonic layer other than the ectoderm is represented. The teratoma, on the other hand, is made up of all three layers of the blastoderm.

2. The situation of the cyst in the anterior mediastinum behind the sternum is explained, although no account is taken of the rigid disposition of the tumor high up in the superior mediastinum and only exceptionally lower down at the level of the diaphragm.

3. Presternal dermoids are well recognised and many of these are found to have no connexion with the mediastinum at all (Clutton, 1887; Bird, 1904; Selby, 1906; Morestin, 1912; Cavalcanti, 1913; MacEwen, 1913; and others). In others it is the presternal dermoid that first attracts attention and at operation for its cure a communication is found piercing the sternum and opening into a second, often a larger, cyst in the mediastinum (Bergman, 1898; Hathaway, 1923). This could be named the "dumb-bell" type of dermoid tumour. Again, there have been cases recorded in which there was no demonstrable presternal cyst but an abnormality of the sternum has been noticed at an operation planned to remove a mediastinal dermoid tumour. Thus, Robertson and Brown (1929) found the sternum bifid, while Körner (1918) saw an opening in the sternum, pencil-sized, against which the tumour was closely apposed. Finally, an intrathoracic cyst is sometimes found firmly attached to the undersurface of the sternum by a distinct pedicle that could be regarded as the homologue or replica of the more perfectly developed canalised "waist" of the dumb-bell tumour. Thus, there is every gradation between a presternal dermoid with no intrathoracic association and a mediastinal cyst isolated from the surface of the body by a normally developed thoracic cage.

Attractive as this dual theory of origin might appear, the evidence adduced in support of a separate aetiology for the dermoid cyst is not irrefutable. The incidence of developmental curiosities of the sternum is small and the number of occasions on which a pedicle has been seen attaching the cyst to the sternum is few when compared with the total number of mediastinal dermoid cysts placed on record, the overwhelming majority of which are entirely intrathoracic and many of them not even adherent to the undersurface of the breast bone.

Moreover, as knowledge of the pathology of these tumours accumulated, many borderline cases were recognised until, finally, it became clear that no simple classification of these tumours into the dermoid cyst, comprising ectodermal structures only, on the one hand, and the teratoma, composed of all three layers of the blastoderm, on the other, was possible. There is little doubt that pure ectodermal cysts, resembling epidermis, do exist but it is possible that had many of the examples so described been submitted to more searching microscopic study, entodermal and mesodermal elements might have been discovered. It was the full realisation of the gradation from simple to complex that led Harrington (1937) to suggest that the terminology should be based on histology, while others workers have coined the name "teratodermoid" to include all forms.

To lay on one side the theory of a dual aetiology and to group all these tumours together postulating a common mode of origin for them serves only to clear the ground and to direct attention to a possible developmental anomaly that takes place in intrauterine life. Several hypotheses have been advanced. Collenberg (1869) suggested that the simple cysts were derived from the ectoderm of the branchial arches and were thus related to the thyroid gland. He was no doubt influenced by the specimen that he was studying, which contained thyroid vesicles, was connected to the gland by a narrow band of tissue, and was supplied with blood by the inferior thyroid artery. Marchand (1883), on the other hand, when discussing a case that was intimately connected with thymus, saw in ectodermal rests in that gland a possible source of the tumour. Other workers have demonstrated thyroid and thymus tissue in their preparations, but it is the exception and not the rule and when observed can be looked upon as a chance outcome of totipotential development. It is unlikely that a teratoma, so complex and primitive in structure and so diverse in form, can be dependent, developmentally, upon any single mature organ of the body, and its origin must be traced to an earlier and less differentiated stage of embryonic life. The "absorbed twin" theory, emanating originally from Dangschat (1903), whereby one "twin" (the autosite) engulfs the other (the parasite), takes cognisance of this and makes the presence of chorionepitheliomatous elements easy to understand. A fanciful variant of this view is the stimulation by a physiochemical process of the segmenting ovum

at the two-cell stage leading to isolation of blastomeres that undergo cleavage. Two identical embryos are produced, one of which becomes parasitic upon inclusion in the midline of the other during the closure of the thorax. Other possible modes of origin are believed to be an extruded polar body or an aberrant sex cell. The latter are found in various positions in the embryo apart from the sex glands and are considered to be capable of parthenogenetic development.

The most reasonable proposition so far propounded is based upon the suggestion of Collenberg that it is in an abnormality of the third and fourth branchial arches that a likely explanation for the origin of these tumours is to be found. It is believed that the cells destined to multiply into the teratoma become separated off at this point and are carried into the thorax by the normal descent of the heart and great vessels. Such a theory accords well with the constant position of these tumours in the anterior mediastinum from the thoracic inlet to the front of the heart. Moreover, it is in the neighbourhood of the third and fourth branchial arches that development assumes its greatest degree of complexity, and ectoderm and entoderm come into a most intimate relationship with each other. This applies particularly to the epithelium, for epithelial elements of all kinds and in profusion are a striking feature of the teratodermoid tumour. Such complexity offers every inducement to misplacement of cells. Finally, it provides a possible reason for the frequency with which these tumours are found adherent to the pericardium and main arterial trunks, a fusion that is sometimes so complete as to defy all attempts at separation.

It must be admitted, however, that each theory has its shortcomings, none fits all the facts, and the final elucidation of this problem must be awaited.

CLINICAL FEATURES

The developmental nature of this group of tumours, taken in conjunction with the customary age at which the benign varieties first make their presence felt, presupposes that many, if not most, of them remain clinically latent for a number of years. This presumption is justified by Case 5 and has, in fact, been recognised for as long as these tumours have been known, for Gordon (1827) ends his original description with these words: "... I should consider the tumour had co-existence with the subject from which it was taken, and was carried without inconvenience, till inflammation in its neighbourhood excited that fluid secretion upon which its enlargement and consequent inconvenience depended." For purposes of presentation, therefore, the clinical manifestations can be conveniently grouped according to the ways in which these tumours eventually become obtrusive.

1. *Growth and the Effects of Pressure.*—A progressive enlargement of the tumour, such as has been noticed to occur most commonly in the third and fourth decades of life, will ultimately produce symptoms due

to the pressure of the mass upon neighbouring structures within the thorax.

Cough, with or without expectoration, is the commonest individual symptom. In type and intensity it displays the utmost variation which is apparent not only when one case is compared with another, but in the evolution of the disease in any one patient.

In the beginning it is short, dry, and irritating and a "barking" quality may be imparted to it and was, indeed, a striking feature of Case 1 of this series. Coughing may be practically constant but more often it is paroxysmal and the spasms, which have been known to last for several minutes at a stretch, are associated with dyspnoea and are sometimes ushered in by attacks of breathlessness (Ekehorn, 1898). The published records contain many instances in which the position of the patient has a noticeable effect upon the cough, the adoption of a certain posture, such as lying on the back or on one or the other side, serving to excite the paroxysm which is relieved as soon as the patient sits erect. Although there is often no close agreement between the situation of the tumour and the position the patient adopts, yet a study of this symptom does suggest that cough and breathlessness are both liable to be provoked by lying flat on the back or upon the side into which the mass projects. This was certainly true of the patient in Case 1, who was always to be found sitting up in bed knowing quite well that were she to lie down breathlessness and a "tickling in the throat" would inevitably follow. Although at this stage the cough is dry and useless it may produce a scanty mucoid expectoration occasionally stained with blood. A streaky haemoptysis, explicable as arising from localised congestion, may be a terminal event of every coughing fit (Bergman, 1898). This dry, hacking cough, so common an early symptom as to be almost universal, may yet be absent throughout the patient's entire illness (Phemister and associates, 1936).

Dyspnoea, with cough, is a complaint more commonly found than any other and is generally first apparent on effort. It may, however, be quite unrelated to exertion and be seen in the form of suffocative attacks that have been described by patients as "smothering spells" or "choking fits." Cordes (1859) mentions the occurrence of periodic asthma, while attacks of urgent dyspnoea with cyanosis have been observed as terminal events. The relationship that dyspnoea bears to posture has already been referred to and careful questioning of a patient, with this in mind, is often helpful in making a diagnosis.

Pain in the chest is frequently encountered in the history of these patients and resembles the pain of pleurisy in so far as it is sharp and lancinating and aggravated by coughing, laughing, deep inspiration, and effort. Pain of this kind is very likely pleural in origin and may be initiated by distension of the cyst stretching the pleural covering, by a drag upon adhesions attaching the tumour to the parietal pleura, or by

an infection of the pleural envelope itself by contiguity or rupture of the cyst.

Pain, however, need not be confined to the chest wall nor need it be pleural in type. In some patients it has been felt in the shoulder with a radiation down the arm, generally along the ulnar side, to cause a feeling of pain or numbness in the hand and fingers. This manifestation was accompanied, in some instances, by paresis of the limb and muscular wasting. Even more remarkable was Tuffier's case (1919). This patient was a man who suffered from attacks of angina pectoris, the cause of which was diagnosed by Vaquez as a mediastinal cyst. At operation a large dermoid cyst was found so closely adherent to the heart and great vessels that the aorta, auricle, and ventricle could be seen beating within it and no pericardium was apparent. The "anginal" pain was completely relieved by a drainage operation and the subsequent piecemeal crushing of the calcareous wall of the tumour. Abdominal pain, as a prominent symptom, has been recorded, and in two cases (Pflanz, 1896, and Harrington, 1933) pain referred to the ear of the same side of the body as the tumour has been described.

Engorgement of the veins of the neck is not uncommonly found in conjunction with swelling of the face, and one jugular vein is sometimes seen standing out more prominently than its fellow on the opposite side. If venous obstruction is of a high grade, oedema of the feet, ascites, and anasarca become evident.

Palpitation of the heart is by no means an infrequent symptom and was one of the earliest noticed by the patient in the first case of this series. It is the result either of pressure upon the heart or of displacement of the organ by the tumour. The rhythm is often found to be irregular. Sauerbruch has drawn attention to the occurrence of paroxysmal tachycardia due to the pressure of mediastinal tumours, a symptom that may also be excited by a tampon used after mediastinal operations and relieved as soon as the plug is removed. In Case 1 the dermoid cyst was so closely adherent to the front of the pericardium that it was impossible at autopsy to separate the two structures, and such close cohesion may help to explain the prominence and early appearance of palpitations. A similar instance of firm union between the tumour and the pericardium is given by Mouat (1909). He experienced the same difficulty at autopsy when he attempted to separate the tumour from the heart and was unable to recognise the pericardium. Tachycardia is important in assessing the risk of major surgery implying, as it does, a long sustained interruption of the normal pace and sometimes rhythm of the heart action.

Pupillary changes have been mentioned in some accounts, but only rarely. A complete Horner's syndrome on the right side due to sympathetic paralysis has been seen in a patient with a dermoid cyst by Heuer (1929).

Alteration of the voice due to pressure on the recurrent laryngeal nerve has been observed. It is more commonly found with tumours that abut towards the left side than towards the right. The voice assumes a husky quality and the change of pitch is usually towards a lower tone. Laryngeal examination may reveal a paralysis of the corresponding vocal cord.

Among the more unusual manifestations of pressure are dysphagia which was encountered by Türk (1903) and, perhaps, pressure upon the vagus nerve can be invoked to explain the case of sudden death that Joël (1890) recounts in a boy of 14 years, about whose previous health nothing was known, who jumped into an omnibus just as it was starting and fell dead. The tumour at autopsy proved to be a teratoma that lay within the pericardium in front of the heart, firmly attached to, but not communicating with, the pulmonary artery.

2. *The Onset of Infection Within a Cyst.*—The advent of infection within a cyst is frequently so dramatic in onset and so grave in outcome that it may be reckoned one of the most dreaded complications of an apparently benign, symptomless dermoid tumor. It is associated, as a rule, with rupture of the cyst wall into a bronchus or pleural cavity and is liable to follow the formation of a fistula. Such an accident occasionally precedes a rapidly fatal result as in the case recorded by Christian (1902) of a woman, aged 38 years, who gave an indefinite chest history for six years, latterly with small haemoptyses and the occasional appearance of hairs in the phlegm. Quite suddenly she spat up a large quantity of blood and pus and died shortly afterward. A similar example, although not so severe, in which a fatal outcome was averted by timely surgical intervention, is recorded by Heuer in 1929. The patient, a coloured labourer, aged 53 years, experienced, during effort, the sudden onset of an acute pain in the right side of the chest together with shortness of breath and cough. The symptoms suggested a spontaneous pneumothorax but an x-ray picture disclosed a cyst with an almost completely calcified wall. It contained air and showed a fluid level, while at one corner of the calcareous envelope a crack was visible at which point a communication with the bronchial tree had become established.

Infection of the contents, however, may occur independently of fistula formation and the accumulation of inflammatory fluid is one possible explanation for that sudden increase in size that these tumours undergo. Moreover, the process may occur silently and unobtrusively as the frequency with which this class of tumour is found adherent to neighbouring structures such as lung and pericardium testifies. Heuer (1929) recounts an experience that has a bearing on this. He removed, without opening the pleura, a dermoid cyst from the right side of the mediastinum of a woman, aged 33 years. The entire tumour was removed but was ruptured during the operation and, although the contents

were evacuated with a gall bladder scoop, a suppurative mediastinitis and empyema of the right side developed. There seemed no just grounds for blaming faulty surgical technique for this complication and Heuer believes that infection can occur at the same time as an acute respiratory illness and persist after the lung inflammation has subsided. The spread of infection from lung to cyst by contiguity is possible but equally possible is the transport of organisms from outlying foci into the tumour by the blood stream.

The end result of bronchial communication and infection is fever often of a hectic type; the expectoration of a large quantity of offensive sputum; haemoptysis, more copious than hitherto and which may be so profuse as to lead to a fatal issue (Ogle, 1897); clubbing of the fingers; cachexia; and death. It is not surprising, therefore, that in the early days the condition should have been misdiagnosed during life and labelled bronchiectasis, empyema, or pulmonary tuberculosis.

3. *The Formation of a Bronchial Fistula Without Obvious Infection.*—In the same way as the cyst contents can become infected without necessarily leading to a bronchial fistula, so a communication between the cyst cavity and the bronchus can become established in the absence of overt infection. That is to say, symptoms may be minimal and easily explained by the effect of pressure and yet careful questioning will reveal the presence in the sputum of "atheromatous matter," "clay-like particles," and hairs that can only have come from the contents of a dermoid cyst, and lead, when recognised, to a confident diagnosis. The subject of sputum examination, however, will be dealt with fully in the section devoted to special investigations.

4. *Presentation of the Tumour in the Neck or Chest.*—It has been possible to collect from the literature twelve instances in which the first clue to the presence of intrathoracic dermoid cyst was furnished by the appearance in the neck of a visible swelling, and in at least two other cases (Gordon, 1827; Poehn, 1871) such a tumour became obvious later in the course of the disease when other manifestations had brought the patient under observation. Soft and fluctuating, sometimes exhibiting pulsation, these tumours, although readily recognised by both doctor and patient, are not always appreciated as the outward sign of an inward and more serious disease. This was particularly evident, and quite understandable, in the days before radiography was employed. Thus, Kückmann (1874) records a soft fluctuating swelling that appeared in the left side of the neck and pushed the sternal end of the clavicle forwards, but it was some months before the diagnosis was finally established, while Koenig (1889) describes the incision of a dermoid cyst presenting in the suprasternal fossa and later trephined the sternum to evacuate the contents. It is remarkable what a long interval can elapse between the advent of a noticeable tumour in the neck and the manifestations of more serious trouble, for Shostak (1904) quotes a

young woman who remembered that she had had a tumour in the neighbourhood of the right jugular vein since childhood which showed no inclination to grow larger until after a chill contracted when she was 22 years of age. This story suggests that infection may have had some influence upon the course of the disease by leading to a sudden enlargement of the cyst. Trauma is another possible predisposing factor, for Jones (1880) related how a boy aged nine years received a blow on the sternum and three weeks later developed a tumour containing milky fluid in the lower part of the neck.

Although the neck is commonly the site at which an intrathoracic dermoid cyst presents when it approaches the surface, this is not invariable and the contents of a cyst, particularly if infected, may, like an empyema necessitatis, appear in other parts of the chest. Mandlebaum, for instance, in 1900, described a swelling in the front of the chest above the right breast at the level of the third rib and von Török, in the same year, recorded the case of a small child who had an abscess in the back three years before the existence of an intrathoracic tumour was suspected. In a separate group should be classed the partially presternal, dumb-bell type of mediastinal cyst.

5. *A Change to Malignancy and the Appearance of Metastases.*—That the onset of malignancy can mark the first departure from good health in one who harbours a benign, symptomless mediastinal tumour is evident from a survey of the published case reports. Thus, in Pinders' first case (1887), autopsy revealed a cyst, with a solid portion that was shown to be malignant, and secondary deposits in the lungs and mediastinal glands. Ritchie, also, in 1903, published an account of a man, aged 24 years, who gave a short history of only three months and whose condition was diagnosed as malignant tumour of the mediastinum with metastases in the lungs. A post-mortem examination disclosed a dermoid tumour with a solid upper pole containing many haemorrhages. Microscopy showed that the solid, haemorrhagic portion was composed of elements resembling a chorionepithelioma. Similar examples were put on record by von Eiselsberg (1903) and Ceelen (1912). The sudden appearance of metastases arising from a tumour that was either symptomless or else looked upon as benign has a bearing on the question of treatment and will be referred to again in that connexion.

PHYSICAL EXAMINATION

Apart from the appearance of the sputum and certain peculiar characteristics that it possesses there is no one physical sign or group of signs that can be regarded as pathognomonic of terato-dermoid tumours of the mediastinum. There may, indeed, be no abnormality detectable upon examination until the thorax is illuminated by x-rays. On the other hand, if pressure symptoms are evident, corresponding signs may be detected which in degree may vary from a disinclination to lie flat to

urgent orthopnoea, venous engorgement of face, chest, and arms with oedema and cyanosis, pupillary changes, and disordered sweating of one-half of the face. In view of the customary position of the tumour in the superior mediastinum such abnormal signs as do exist will be elicited in the early stages in the front of the chest.

The affected side may display a noticeable bulging and Harrington (1933) tells of a young man whose tailor was the first to draw attention to an asymmetry of the chest wall five years before symptoms became added. Apart, however, from a homogeneous unilateral fullness of the thorax and the smaller and more circumscribed swellings in the neck and chest to which reference has already been made, Case 1 illustrates how a localised area of pulsation can be a striking, if albeit a misleading, feature. Movement is usually found restricted on the side of the chest into which the major portion of the mass projects.

Palpation will help to confirm a localised fullness of the thorax and any limitation of movement; it will also enable a more detailed investigation of pulsation to be made and the position of the heart's apex beat to be accurately fixed. The impulse is often displaced by anteriorly placed mediastinal tumours.

The resonance of the percussion note is impaired over a tumour of even moderate size and such an area of dullness can often be mapped on the front of the chest although the lower limit of this impairment is sometimes difficult to dissemble from the cardiac dullness with which it merges.

The breath sounds and the conduction of the spoken voice are faint or absent over the tumour. With the stethoscope, too, cardiac bruits, at the apex or at the base of the heart, can sometimes be detected and their correct interpretation is difficult.

The physical signs so far enumerated are largely referable to the mass itself; in addition, there must be recognised those signs dependent upon secondary changes in the lungs such as atelectasis and suppuration. Attendant collapse of lung can, upon occasion, simulate a pleural effusion and when a collection of serous fluid, or even an empyema, overlies the tumour the recognition of the primary cause is no easy matter. The advent of infection of the contents of a cyst with a bronchial fistula and possibly secondary suppurative changes in the lung brings as dramatic a change to the physical signs as it does to the presenting symptoms. A study of past descriptions of this malady, read in the light of modern knowledge, excites little wonder that our predecessors in the middle of the last century, compelled as they were to rely more upon an expert use of the natural senses than upon supplementary aids to implement the diagnosis, were often beguiled into error.

SPECIAL INVESTIGATIONS

Examination of Sputum.—A discussion of the characteristics of the sputum in this disease has purposely been postponed until now, in or-

der that it may be dealt with as a whole. Careful interrogation of the patient and skillful examination of the sputum will occasionally bring to light the only diagnostic symptom and the only pathognomonic sign of an intrathoracic dermoid cyst—the expectoration of hair and sebaceous matter.

It has been possible to collect from the literature twenty-three instances where specific mention is made of the presence of hair in the sputum. The first recorded case is that of Muntz (1839), in a woman of 28 years, who stated that she had spat up hairs in the phlegm after forceful coughing ever since the age of 15 years.

In the early years before the existence of these tumours became generally recognised, the complaint of coughing up hairs was viewed with scepticism by those in attendance. Thus, Godlee, in 1889, relates how this symptom was received with amusement by the patient's husband and with incredulity by the doctor in charge, both of whom came to the conclusion that the source of the hair was a shawl that the woman was accustomed to wear. It was not until Godlee resected a rib with intent to drain an "empyema" and evacuated hairs with his exploring finger that the patient's observation was at last believed and correctly interpreted. Similarly, in Cloetta's case (1861) the expectoration of hairs in quantity was regarded by the doctor as a deception. Even nearer to our own time the significance of this symptom has not always been appreciated for Becker, in 1927, described how a woman always produced hairs whenever she had an haemoptysis and yet the true diagnosis remained unsuspected until an artificial pneumothorax had been induced and a thoracoscopy performed; while Eloesser (1933) relates how the persistent disregard of the husband's statement that hairs were seen at intervals in the phlegm led to the retention of a woman in a sanatorium for two years with presumed pulmonary tuberculosis. Nevertheless, earlier observers were not slow to realise the importance of this symptom for it was upon this observation that Nobiling, in 1869, based the first correct diagnosis of the disease made before death. Chronologically, Nobiling's case was only the third to be recorded in which this phenomenon had been witnessed.

The hairs are often expectorated singly and appear at intervals spread over a long period before more distressing symptoms supervene. As trichoptysis implies a cyst-bronchial communication, it is evident that such a communication can exist for several years without serious infection of the contents taking place. This phenomenon is not unique and has a parallel in certain cases of tuberculous pyopneumothorax in which a bronchopleural fistula can be demonstrated and yet the pus remains repeatedly sterile on culture for secondary organisms. A statement is frequently seen in the published accounts to the effect that hairs are voided only on forceful coughing. This suggests the operation of

a valve mechanism that will permit the escape of cyst contents when the act of coughing is vigorous but acts as a barrier to the passage of air and infection in the opposite direction. An alternative explanation is that the greasy, sebaceous contents of a cyst act as an efficient barrier to the exit of hair by blocking the opening. It is only when expiration is sudden and forceful that this plug is dislodged. It is by no means rare, however, to notice that the hairs in the sputum mug are matted together or attached to concretions composed of fatty and atheromatous matter. Frogman exhibited such concrements before the Society of Swedish Physicians (Ekehorn, 1898) and Heuer (1929) records the expectoration of "claylike particles" with hairs attached. The colour of the strands bears no relationship to the natural colour of the hair of the host, the hue being as a rule nondescript, occasionally blonde, and in one instance reddish.

In other respects the examination of the sputum supplies valuable additional evidence of a dermoid cyst. Sebaceous matter, with its oily, greasy consistency, is characteristic and fat droplets may be seen. More solid elements are sometimes forthcoming, which have been described as atheromatous matter and claylike particles. Cholesterin crystals are distinctive but not pathognomonic and can be recognised by the glistening, opalescent sheen that they impart to the surface of the fluid. Finally, reference must be made to the observation by Foucher (1901) of small, yellow, round balls resembling actinomycotic granules that occurred in a sample of sputum, and similar bodies were noticed in the fluid removed during the exploration of a cyst by Fanano (1937).

Exploration of the Cyst or of a Presenting Swelling.—The contents of a cyst have been tapped on numerous occasions in the mistaken belief that the diagnosis was a pleural effusion, and in some cases the disease has remained unrecognised until a rib has been resected for an "empyema thoracis." In either event the character of the fluid obtained was sufficient to clear up the diagnosis in most instances. It must be remembered, however, when a formal exploration of a cyst is contemplated, that unless a wide bored needle is used, a "dry tap" is likely to result owing to the thickness of the fluid that is sometimes encountered.

Although exploratory puncture has been safely and successfully accomplished and information of value obtained from the procedure it is not to be lightheartedly recommended. To drive a needle of wide bore across what may be a free pleural space into a cyst that is very likely under tension is fraught with the danger of the escape of the contents into the pleural cavity there to excite a serous effusion or an empyema. There is greater justification, however, for needling a presenting swelling of the chest wall. It can be assumed with some confidence that in that situation the two layers of the pleura will have become firmly united and the danger of defiling the pleural space is negligible. Even so, the

exact position of the adherent area must be first checked by x-ray localisation. Apart from this solitary exception, diagnostic exploration should not be carried out as a routine procedure as the difficulty of determining whether the pleural space is free or otherwise is great, while if the true nature of an intrathoracic dermoid cyst is uncertain, an aneurysm of the aorta is presumably still one of the possible diagnoses.

Radiology.—As in every department of modern chest medicine, radiology has contributed in no small measure to the early and accurate recognition of intrathoracic tumours. The x-ray film of today rivals the autopsy table of yesterday in supplying the first intimation of the presence of a mediastinal dermoid cyst. Moreover, there is every likelihood of an increase in the number of symptomless tumours recognised in this way if mass radiology for the detection of early pulmonary tuberculosis is seriously applied to large groups of people or to militiamen.

Türk (1903) was the first to apply radiography to the diagnosis of an intrathoracic dermoid cyst and from that date onwards an anteroposterior picture of the chest has been usefully employed, not only in envisaging the tumour, but in separating from the main mass such complications as pleural effusion or secondary pulmonary abscess. It has only recently been realised, however, that a radiological investigation is incomplete if one picture taken in one plane only is studied. A lateral view of the chest, in conjunction with an anteroposterior picture, is necessary if a sound opinion is to be formed as to the probable nature of a mediastinal opacity.

A study of a terato-dermoid tumour in these two planes will show that it is usually circular or globular in shape with a clear-cut edge. The contour, however, may be irregular and lobulated, and Hammarskjöld (1934) attaches importance to this in distinguishing a solid teratoma, with its bossing, from the uniform and smooth margin of the dermoid cyst. Another point of the utmost diagnostic importance is the position of the shadow. Clinical examination will often suggest that it lies in front; the lateral picture confirms this impression by showing that it occupies the anterior compartment of the mediastinum immediately beneath the sternum. There are few other intrathoracic tumours that are similarly disposed. This fact is clearly brought out in the x-ray reproductions of the first four cases here described. But the value of the lateral picture is not confined to fixing the site of the tumour; in conjunction with oblique views it will sometimes demonstrate a pedicle that attaches the tumour to the mediastinum or sternum. This observation was first made by Hammarskjöld (1934). The pedicle is not always present and is not always apparent radiographically but, if it is seen, it possesses diagnostic significance and has recently been recognised and correctly interpreted by Harrington (1937) and by Smith and Mills (1938).

The main mass of the tumour, as a rule, has a homogeneous density but occasionally this uniformity is interrupted by small, more opaque areas that can be identified as teeth or plaques of bone (Singer, 1928; Lamarque and Chaptal, 1930; Bengolea, 1933; Harrington, 1933; Lambret, 1933; Harrington, 1937). This greatly assists in the diagnosis. Areas of calcification in the wall of a cyst are also opaque to x-rays and rarely the wall is wholly composed of calcareous matter resembling a shell. Difficulty may sometimes be met in differentiating bone and teeth from calcareous deposits in lung and hilar glands, but lateral or oblique skiagrams will show that the opacity lies in the wall or substance of the tumour and not outside of it.

A skiagram taken in the erect position will sometimes disclose a fluid level in the mass. This is an important observation, indicating that the major portion of the mass is cystic and that communication with a bronchus exists. If, in addition to a fluid level, the tumour can be demonstrated in the anterior mediastinum no other diagnosis than a dermoid cyst is permissible on radiological grounds. Phemister and his coworkers (1936) have recently made an interesting radiological study of a dermoid cyst of the mediastinum and have demonstrated a "fluid level" in it in the absence of air and, hence, in the absence of a cyst-bronchial communication. Their contention is that, provided the patient sits quite still and erect for a short time before the picture is taken, the fat in a cyst will separate off from the aqueous contents at body temperature and rise to the surface like cream, a line of demarcation forming between them. The cyst they studied was removed at operation, and an x-ray picture taken of the excised tumour again showed the "fluid level." After cooling, the fat broke up into clumps, floated in the aqueous fluid, and the phenomenon was no longer seen. A portion of the cooled contents was heated in a cylindrical vessel and brought to 37° C. and maintained thus for twenty-four hours. The fat became fluid and the line of separation on an x-ray film was obvious. It is not always possible to demonstrate Phemister's line and its existence may, to some extent, depend upon the nature of the fat. This has only been chemically analysed in a few isolated instances.

Bronchography with opaque oil does not occupy such an important place in the investigation of intrathoracic tumours as it does in other forms of nontuberculous pulmonary disease. Kerr and Warfield (1928) employed lipiodol for the first time to reveal bronchial narrowing due to a cyst but the pioneer of "contrast radiography," used in its broadest sense, was Morone (1909), who injected milk of bismuth into a sinus in the neck and an x-ray picture of the chest showed that the sinus communicated with a cavity behind the sternum. For one purpose, however, bronchography is invaluable. It is often difficult to be certain how far such symptoms as foetid expectoration or haemoptysis are attributable to an infected cyst or to secondary bronchiec-

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tatic changes. It is important that this distinction should be made if radical surgery is contemplated lest too rosy a hope of complete and lasting recovery is placed in an operation that is inevitably difficult and dangerous. A successful bronchogram will supply the answer.

The kymogram gives an interesting pictorial record of pulsation but its usefulness will remain limited until it is possible to infer more accurately than at present whether such pulsation is inherent or transmitted. A benign tumour will often display more vigorous "notching" of its edge than an aneurysm of the aorta. Likewise, the tomogram offers relatively little information of value.

Fluoroscopic screening of the patient is helpful. Minute detail cannot be expected of this method but the relationship of well-defined structures within the chest can be made out with an accuracy that a series of films will often fail to supply. Moreover, it will assist in finding the correct angle at which to take a permanent oblique record. A careful screening of the patient is indispensable in differentiating between a tumour and an aneurysm of the aorta, while a barium swallow not only outlines a portion of the aorta but demonstrates any interference there may be with the function of the oesophagus.

Thoracoscopy.—The inspection of a mediastinal tumour with a thoracoscope after a preliminary pneumothorax has been induced will occasionally supply valuable information. In Becker's case (1927), for instance, this procedure led to the correct diagnosis of a dermoid cyst after a label of bronchiectasis had been attached to the patient for two years. By this means the smooth, glistening wall of the tumour can be visualised and the nature and extent of the attachment to surrounding organs can be assessed. Moreover, with a one-cannula operating instrument of the Chandler pattern the tumour can be palpated with the blunt-ended diathermy knob and a conclusion reached as to whether it is predominantly cystic or solid. It would be wise, however, to refrain from any attempt to aspirate the contents in the presence of a free and uninfected pleural space.

Bronchoscopy.—In the investigation of a solid mediastinal tumour, bronchoscopic examination is of limited value and is confined to demonstrating a narrowing of the lumen of the tube from pressure exerted from outside. If the tumour is cystic and a fistula exists, more information from endoscopy may be expected. Thus, the characteristic contents of the cyst might be obtained for the first time by bronchoscopic aspiration, while the appearance of pus welling up from the tubes distal to the opening of the cyst should arouse suspicion of secondary bronchiectasis. In Case 5, reported in this communication, a portion of tissue removed through the bronchoscope bore a close resemblance to skin and did not suggest bronchial mucous membrane. This biopsy was strongly in favour of a tumour of the dermoid type.

The Aschheim-Zondek Test.—The Aschheim-Zondek or Friedman test deserves prominence in this discussion not so much for the diagnostic aid that it has rendered in the past as for the help it might give in the future. Up to the present it has seldom been applied to mediastinal tumours.

Zondek, in 1929, showed that men suffering from teratoma of the testis excreted prolan A in the urine and gave a positive Aschheim-Zondek test. Work was extended along the same lines by Ferguson (1934), who found that in 117 consecutive cases of teratoma testis all gave a positive result in contrast with 100 cases of benign lesions of the organ in which the result was invariably negative. He concludes that a significant excretion of prolan A in the urine (500 mouse units per litre) has never been observed in the male except in teratoma testis, extragenital teratoma, or chorionepithelioma. Furthermore, if the primary tumour of the testis is removed the reaction becomes negative within seven days of operation and the presence of metastatic deposits can be inferred from a return of a positive Aschheim-Zondek test anytime up to three months before symptoms or physical signs become evident. By putting the test on a quantitative basis, Ferguson showed that of all the types of embryonal tumours of the testis the chorionepithelioma led to the greatest excretion of prolan A.

The application of this work to mediastinal tumours will be appreciated when it is recalled that many teratomata found in the mediastinum are composed of undifferentiated tissue that in some instances has been designated chorionepitheliomatous. A positive Aschheim-Zondek test in a man with a normal testis, or in a female if pregnancy can be excluded, together with the radiological demonstration of a mediastinal opacity would go a long way toward disclosing the teratomatous, and probably malignant, nature, of the latter. Hammarskjöld (1934) found a doubtful positive Aschheim-Zondek test in a male, aged 22 years, who was operated upon for an intrathoracic tumour which was later shown to be a teratoma with malignant change, while two years previously Kantrowitz (1932) had reported a case of a 22-year-old male who was found, at autopsy, to have a teratoma of the anterior mediastinum containing chorionepitheliomatous elements with a positive Aschheim-Zondek test in the urine and in extracts of the tumour tissue. Admittedly, a necessary step in the diagnosis of a primary extragenital chorionepithelioma in the male is a careful histological examination of the testes, and it is doubtless true that in many cases so designated this examination has not been sufficiently searching. In Kantrowitz's case already quoted, many thin sections of the testicles were studied before the organs were pronounced free of tumour cells. Frank's (1932) contention, therefore, that where a circumscribed three-layered teratoma is found in the mediastinum, it can be definitely stated that the primary origin of the chorionepithelioma is at that site is upheld. Friedman's

modification of this test has been carried out upon three of the patients reported in this communication and they all were negative. In two of them it was possible to prove a dermoid cyst, which would not be expected on theoretical grounds to give a positive result, and the nature of the tumour in the third (Case 4) is still unknown. It is likely that the performance of this test as a routine in doubtful cases of mediastinal tumours will, in the future, be of diagnostic and prognostic value.

DIFFERENTIAL DIAGNOSIS

It is often difficult to establish correctly the nature of a presumed intrathoracic mass or even to infer with certainty from which organ or structure it arises. Yet it is desirable, in the interests of prognosis, to reach a correct diagnosis before exploratory thoracotomy is advised. In those cases of terato-dermoid tumours in which hairs and sebaceous matter are found in the sputum there is no difficulty; in others a shrewd idea of the probable nature of the affection can be formed after an intensive investigation; whereas, in other examples, the diagnosis is either temporarily masked by such complicating factors as effusion or suppuration or cannot be made on the existing evidence.

Before the x-ray plate was available to act as a check upon the physical findings the label *pleural effusion* or *empyema* was one often attached to a patient and the true nature of the illness was not appreciated until after exploratory puncture or a drainage operation had been performed. The problem is greater when a true effusion of either serous fluid or pus has formed as a complication, for such a collection of liquid can effectively conceal an underlying tumour until air replacement and a skiagram taken with the patient erect allows a more detailed radiological examination of the lung and mediastinum above the fluid level. Thus, a surgeon may be faced with a chronic empyema cavity which has defied treatment by rib resection and drainage, the existence of a dermoid cyst as the provocative agent only being disclosed when a major operation is performed.

Suppurative conditions within the chest, *lung abscess* and *bronchiectasis,* which may be secondary to the tumour are liable to be looked upon as the sole disease present. Conversely, a patient who is known to have an infected dermoid cyst should be investigated in order to exclude secondary pulmonary suppuration as a contributory cause of the symptoms in view of the important bearing that this may have upon treatment. An acute respiratory illness such as *pneumonia* has been responsible for confusion in former years. It is probable that genuine attacks of pneumonia occur in persons harbouring a cyst with a frequency greater than the average, and may be recurrent; there is little doubt, however, that pneumonia has often been the term applied to an infection of the contents of a dermoid cyst. *Pulmonary tuberculosis,* as an independent disease, has several times been reported in conjunction with

a tumour, proof resting upon post-mortem examination. In other accounts the clinical diagnosis of phthisis or consumption was later found to have been incorrect, the symptoms being the result of the complicating factor of infection. Today, when the sputum is examined for Koch's bacillus almost as a routine and the application of x-rays to diagnosis has become universal, such confusion has only to arise to be dispelled.

It will generally be only a matter of time before the foregoing conditions are distinguished from the class of tumour under discussion or else allotted their rightful, subordinate place in the clinical picture. The differential diagnosis between the terato-dermoid tumour of the mediastinum and other types of tumour occurring in the thorax is harder to reach. The more characteristic features of the terato-dermoid tumour have already been described and it follows that in this differentiation the greatest difficulty will be experienced in the case of those tumours that lie towards the front of the chest beneath the sternum. Tumours of the thymus gland illustrate this point. Histologically, these tumours form a complex group that has so far defied successful classification and for this reason the term *thymoma* is used to embrace all varieties. Many of these tumours are highly malignant and almost all of them are locally invasive. Among the ill-defined variations and transitional forms of this group is included the lymphosarcoma, which is fairly generally recognised, while the use made by some authors of the term teratoid type of malignant thymoma (Andrus and Foot, 1937) emphasises the structural similarity that may exist betwen thymoma and teratoma. Clinically, the comparatively short history associated with the symptoms and signs of malignancy serves to distinguish a thymoma from all but the malignant forms of the terato-dermoid class of tumour, although the position in the mediastinum occupied by both groups is identical. Moreover, the response to deep x-ray therapy is a valuable aid to diagnosis, for while lymphosarcoma and malignant thymoma are both radiosensitive the teratoma remains unchanged. Finally, use may be made of the observation that in some instances a tumour of the thymus is associated with the clinical features of myasthenia gravis (Norris, 1936).

Lipomata and *fibrolipomata* have been recorded in the mediastinum and may attain to a great size. Their presence can be inferred by means of an exploring needle, as a "dry tap" will result even if a needle of wide bore is used. No firm resistance is encountered and a sensation similar to probing a pat of butter is experienced (Walker, 1936-37).

Carcinoma of the bronchus, particularly the "paramediastinal" form with a sharply defined lateral edge, must be considered although in most cases in which the true nature of this condition is in doubt confusion arises over other causes of pulmonary atelectasis, suppurative or chronic inflammatory changes, or other affections of the mediastinal glands. Rarely, however, a carcinoma of bronchus can develop in such a way as

to resemble closely a teratoma. An example of this has recently been studied at the London Chest Hospital. The patient, a married woman aged 24 years, was admitted for investigation with a provisional diagnosis, made by a radiologist, of a dermoid cyst of the mediastinum. The tumour lay in front of the chest and possessed a clear-cut posterior edge. It had invaded the chest wall to present as a swelling in the region of the second left interspace. The diagnosis of carcinoma was finally made by exploring the presenting swelling and removing a piece of tissue for biopsy. Another variety of malignant tumour that deserves mention is that first described by Pancoast, in 1932, and called the *superior pulmonary sulcus tumour.* It lies in the thoracic inlet and is characterised by pain and numbness down the arm of the same side of the body as the tumour with wasting of the small muscles of the hand, Horner's syndrome, erosion of the ribs and vertebral bodies, and a relatively small opacity on the x-ray plate at the summit of one apex. Pancoast originally believed that these tumours were embryonal in origin, but a recent study by Owen, Hewer, and Whitaker (1938) suggests that they are more probably apical bronchogenic carcinomata. In any event, their clinical manifestations are more dependent upon their position in the chest than on their essential pathology and there seems little justification for perpetuating a separate aetiology and distinctive title for these growths.

Tumours that are found almost exclusively in the posterior mediastinum are only very rarely teratomatous in origin and, hence, the position in the chest that the tumour occupies, as revealed by a lateral x-ray picture, is of the utmost importance. Admittedly, Fuller and Jagger (1927) have recorded a dermoid cyst of the back which lay in the erector spinae muscle, but there was no evidence that its site of origin was mediastinal or even intrathoracic. In view of the fact, however, that tumours situated behind do occasionally advance forward they may cause difficulty and so enter into the differential diagnosis. They include the *neurofibroma,* the *ganglioneuroma,* and the *xanthoma,* a curious, yellow-tinged, benign tumour of uncertain aetiology and great rarity that has been made the subject for study by Phillips (1938). These are often amenable to surgery. The neurofibromata and ganglioneuromata are closely allied and have been classed together as "neurinomata" (Carrière and Huriez, 1937). Histologically, those tumours exhibit an extreme degree of pleomorphism and examples are found exhibiting every gradation from well-differentiated to undifferentiated cells. With lack of differentiation goes malignancy and these are the types commonly found in children; occurring in adult life the tumour is more usually benign. Thus, Cooley and MacNamara (1940) record the case of a medical practitioner, aged 62 years, who died of pneumonia. He was known to have had a thoracic tumour for eighteen years and at autopsy this was proved to be a ganglioneuroma. These tumours are

more commonly found high in the chest and in the paravertebral gutter; the capsule is sometimes incomplete and they may invade the spinal cord, while the recognition of Horner's syndrome, if this is present, is a valuable aetiological sign.

An intrathoracic *cystic lymphagioma* has been recorded. It usually arises from the posterior mediastinum and is composed of many cystic spaces containing a watery fluid. It can sometimes be surgically removed (Skinner and Hobbs, 1936).

There is one variety of mediastinal cyst, believed to be congenital and embryogenic in origin, that in the literature seems, in many cases, to have been confused with a teratoma. It is the *mediastinal cyst of gastrogenic and bronchogenic origin.* Morley Fletcher (1897) recorded the first example that it has been possible to trace, in a girl aged 6 years. He regarded the specimen as a congenital cyst arising in connection with the foetal oesophagus. Mixter and Stewart (1929) and R. E. Smith (1930) have contributed further examples. Histologically, the wall of the cyst in some specimens is indistinguishable from normal stomach, in others it resembles bronchus, while in a few both types of tissue are found. Their structure which conforms to a distinct pattern and is more stereotyped than the teratomatous cyst, their position in the posterior mediastinum, and their clinical recognition at a relatively early age form good grounds for invoking for them an aetiology different from that of the teratomata already described.

Passing reference must be made to certain well-recognised causes of *mediastinal glandular enlargement*—tuberculosis, Hodgkin's disease, gummatous infiltration, carcinomatous deposits, myeloid and lymphatic leukaemia—if such glandular masses are not to constitute a diagnostic error. Each of these conditions presents certain individual clinical features or else is amenable to specific laboratory and therapeutic tests the proper evaluation of which, combined with a radiographic demonstration that the mass is central and not anterior in position, should enable the correct diagnosis to be reached after only transient hesitation.

There are two affections of the cardiovascular system that enter into the differential diagnosis of the tumours under consideration: *aneurysm of the aorta* and *cysts of the pericardium.*

The distinction between thoracic aneurysm and tumour is not always easy to draw and in spite of modern methods of investigation there is no occasion today to disagree with Graham Steele (1911) who, in a Bradshaw lecture devoted to this subject, remarked, "All who have had much acquaintance with the two conditions—neoplasm and aneurysm within the chest—will, I think, admit the difficulty occasionally experienced in distinguishing between them, even when the greatest care is taken." That a saccular aneurysm arising from the first part of the aorta and extending forwards can so closely resemble a dermoid cyst or benign tumour of the mediastinum as to cause per-

plexity is evident from the rare occasions in which an exploratory thoracotomy has been undertaken. In one such instance, studied at the London Chest Hospital in 1935, it was the absence of pulsation that falsely suggested the possibility of a benign tumour. Even when the chest was opened there was no pulsation apparent to the eyes or the fingers. The x-ray pictures of this case, which are similar to those of a dermoid cyst, have been reproduced in an article by Sparks (1937-38). The clinical appreciation of pulsation of an intrathoracic mass has for many years been taken as presumptive evidence of an aneurysmal origin. Now that fluoroscopy and the kymogram have proved an advance on palpation in the detection of pulsation, and in view of the difficulty of determining by such means the inherent or transmitted nature of the pulsation observed, some revision of the significance of this sign as a point in the differential diagnosis between aneurysm and neoplasm is needed. In fact, recent clinical and fluoroscopic studies suggest that the converse of what has been traditionally believed is more often true, namely, that it is the tumour which pulsates and the aneurysmal sac which may fail to do so. Thus, Burvill-Holmes (1934), discussing this subject, attaches little importance to pulsation and remarks that, in his experience, pulsation of an aneurysmal sac is the exception rather than the rule. A possible explanation is this: a saccular aneurysm may communicate with the parent vessel through a relatively narrow ostium and its inner wall becomes lined by a layer of clot. Only a limited and sluggish circulation, therefore, is possible within the sac and this is insufficient to endow the sac with inherent pulsation. It follows that any pulsation that is apparent must be transmitted, the driving force being a diseased and enfeebled syphilitic aorta. A tumour, on the other hand, rests upon a normal, healthy vessel and has a vigorous pulsation imparted to it which the tumour, in its turn, transmits. Although in the differential diagnosis between these two conditions the presence or absence of pulsation must be carefully looked for and the result correctly interpreted, there are other points which will help in the decision. These include the fluoroscopic visualisation of the aorta, if possible throughout its whole length; the quality of the aortic second sound and the presence of aortic regurgitation; the age of the patient; and the serological tests for syphilis which are usually, but not invariably, positive in aneurysm. Such signs as tracheal tugging and a displacement outwards of the apex beat are open to misinterpretation and the possibility of syphilis and a dermoid cyst occurring together in the same patient should not be overlooked (Gallavardin and Bocca, 1921).

Of the pericardial cysts, the one most likely to cause confusion with the terato-dermoid tumour is the so-called inflammatory pericardial diverticulum which has been comprehensively studied by Kienböck (1927) and Kienböck and Weiss (1929). These cysts are believed to be encapsulated, saccular collections of fluid resulting from a previous

pericarditis. They are seen, radiologically, as oval, multiangular, often pulsating, masses more often jutting out from the right heart border than the left. In the successful recognition of these diverticula Kienböck stresses the importance of remembering their existence, their stationary size over a long observation period, the detection of cardiac dilatation, and the normal appearance of the aorta.

There remains to be enumerated a number of other conditions that may be confused with terato-dermoid tumours of the mediastinum:

Solitary cyst of the lung or bronchus may temporarily give rise to doubt, especially if the cyst is filled with fluid and lies anteriorly beneath the sternum. This type of cyst, of which the "paratracheal" cyst is a variety and which probably bears a developmental affinity to those of bronchogenic origin already discussed, and the dermoid tumor under consideration have both, at times, to be differentiated from an *encysted interlobar empyema.*

Hydatid cyst of the mediastinum, although rare in this country, enters into the differential diagnosis in districts where echinococcal infection is rife. The expectoration of the characteristic sputum containing hooklets clinches the diagnosis while the complement fixation test and Casoni reaction supply useful evidence.

Retrosternal goitre, particularly if unaccompanied by thyrotoxic symptoms or signs, may so resemble a mediastinal tumour as to remain undetected until operation. The characteristic wedge-shaped opacity on the x-ray plate is not always recognisable, and the elevation on swallowing is not always detected nor is it pathognomonic of substernal goitre. The demonstration of calcium in the mass on the x-ray film, when it occurs, is an added cause of confusion.

Achalasia of the cardia with a *megaoesophagus* can also simulate a mediastinal mass until a barium swallow clears up the diagnosis (Chandler, 1939). *Spinal caries* with a cold abscess tracking forwards is another condition that must be borne in mind, for Fanano (1937) in his account of a case of a mediastinal dermoid cyst mentions how such a cold abscess had presented similar signs. Careful radiography in the lateral plane and the exploring needle should dispel all doubt.

COMPLICATIONS AND TREATMENT

The only form of treatment that will prove of any lasting avail for a teratoma of the mediastinum is surgical intervention. All measures of a medical character must be viewed as purely palliative; deep x-ray therapy and radium, which would not be expected to influence the course of a benign dermoid cyst, has been found disappointing even when applied to a malignant teratoma. Thus, Bevan (1933) inserted radium needles before advising surgery in an infected dermoid cyst without any effect upon the size of the tumour or the quantity of discharge, while

Hammarskjöld (1934) failed with deep x-rays in a teratoma that was subsequently shown to contain chorionepitheliomatous elements. Repeated aspiration of the contents of an infected dermoid cyst that is adherent to the chest wall will temporarily relieve such distressing symptoms as cough, dyspnoea, and profuse expectoration but amelioration will be short-lived.

The surgical approach to an intrathoracic tumour should never be lightheartedly recommended despite the comparative safety with which an exploratory thoracotomy can now be undertaken, for any attempt to remove the tumour entails a potential risk to the life of the patient. For this reason it is necessary, before embarking upon a discussion of the possible methods of operative treatment and their results, to form some idea of the ultimate fate of such a tumour if it is left alone and to call to mind certain complications and accidents to which these tumours are singularly liable and which, if allowed to occur and progress, so hamper the surgeon as to render his task many times more difficult than it need be if not actually impossible of execution. This applies particularly to those tumours which in the future may be first recognised by routine radiography at a stage when symptoms are absent.

There are a few instances in which the tumour has been discovered accidentally either in the course of a routine autopsy performed for an independent disease or during an anatomical dissection, and out of the records of 209 cases that have been consulted there were nine, or 4.3 per cent, in which it was clear that the tumour did not contribute in any way to the cause of death. In eight of these it was a teratoma of the dermoid type and in only one was it a more complex teratoma with multiple cystic spaces. The cause of death and the age of the patients in these cases were as follows: pneumonia, 61 years (Foà, 1874); bulbar paralysis, 53 years (Pinders' second case, 1887); tuberculous meningitis, 30 years (Marfan, 1891); pulmonary tuberculosis, 30 years (Kretz, 1893); phthisis, 37 years (Sommers, 1901); discovered during dissection (Ferra and Sice, 1910); gunshot wound in battle, 25 years (Hörnicke, 1922); pulmonary embolism following laparotomy, 65 years (Gordon's second case, 1930), and carcinoma of the stomach, 61 years (De Stella and Beerens, 1935). The average age in this list is noticeably higher than is usual in this disease and if it is assumed that the younger patients would have continued symptom-free in the absence of intercurrent disease or violence, an event which is unlikely, it would seem that only 4.3 per cent of terato-dermoid tumours fail to produce symptoms at some stage in the course of their career.

Second, a study has been made of the histories of those patients with a terato-dermoid tumour who died of this disease and who were submitted to no form of active treatment other then exploratory puncture. There were forty-seven such examples. In forty of these patients the

duration of symptoms referable to the tumour is given with some exactitude while in the remainder the author has been content to employ such phrases as "sudden acute illness," "acute pneumonia," "long illness," "sudden death," "a few weeks," etc., in his description of the course of the disease. In the forty cases in which the facts are either given or can be worked out, including both the benign and malignant forms, the length of history was found to vary from fourteen years to two weeks and the average length of time elapsing between the first unequivocal symptom of the disease and the death of the patient proved to be 1.8 years. When account is taken of the diversity of course that the disease runs it is clear that this figure of 1.8 years as the average span of life of the recognised but untreated tumour has obvious limitations from the practical viewpoint. Yet it serves to emphasise the need for treatment more especially when it is recalled that it is in the late teens, twenties, and early thirties that the first symptom comes to light in most cases.

Those complications and episodes that are liable to develop and that require surgical intervention to relieve or to prevent them can be conveniently grouped under five headings:

1. *A progressive increase in size:* An increase in size commonly occurs, as has been stated, in the third and fourth decades and leads to purely pressure symptoms. If surgical treatment is contemplated it should be applied early because the attendant risks increase more in a geometrical than an arithmetical progression with an increase in the size of the tumour. Allow the tumour to double itself in size and the difficulty and danger of its complete extirpation are increased almost fourfold. Growth as a rule is not rapid and any tendency for it to occur can be recognised early by serial x-ray pictures.

2. *The spontaneous development of a cyst-bronchial communication:* The development of such a fistula can occur instantaneously and lead to sudden death following haemoptysis or to a quick decease consequent upon infection of the cyst contents or secondary pulmonary suppuration. More often the disease assumes that slow, progressive, downhill course associated with chronic intrathoracic suppuration and with an accompanying deterioration in the general health and resisting powers of the patient that the thoracic surgeon has learned to dread. A parallel is seen in the difference in the mortality figures of a lobectomy performed upon a "clean" case of bronchiectasis and a similar operation undertaken after months of infection have laid their stamp upon the patient (Romanis and Sellors, 1936). If success is to be achieved the surgeon should be allowed to forestall infection and not be asked to cure it.

3. *Rupture into adjoining structures:* The bronchus is the commonest structure so implicated and by virtue of its importance has been discussed separately (vide supra). Other instances of ruptures

have been recorded, such as those into the aorta (Büchner, 1853), pericardium (Cordes, 1859), superior vena cava (Stein, 1917), and pleural cavity (Wheeler, 1939). With the exception of the last named, surgical relief either will be sought with but a slender chance of success or will come too late.

4. *The development of adhesion binding the tumour to related structures:* Development of adhesion is, to some extent, dependent upon infection but may occur in the absence of any obvious infection of the contents of a dermoid cyst. In this latter group the mechanism of the production of such adhesions has given rise to speculation. They may possibly be the direct result of previous independent respiratory illnesses such as pneumonia and influenza, or it may be that the situation of the tumour upon a constantly beating heart gives rise to adhesions due to a continuous minor trauma associated with this pulsation. At all events it is evident that the longer a tumour is allowed to remain within the chest the greater will be the opportunity for such adhesions to develop to the embarrassment of the surgeon once the decision to operate has been reached.

5. *The change to malignancy:* When once the conversion from benignity to malignancy has taken place there is very little chance of ultimate recovery. No case can be traced in the literature in which a radical operation in such circumstances has proved permanently successful. Of the 209 reported cases in the literature that have been consulted for details, twenty-seven were malignant and this does not include Lanza's (1937) unique example of a secondary deposit from a primary laryngeal growth found in a simple dermoid cyst. This puts the incidence of malignancy at 12.9 per cent which agrees well with Jacobs' (1929) estimate of 10 per cent. Malignant transformation in a previously benign tumour can occur at any time and the change may be unaccompanied by any collateral phenomenon such as a sudden increase in the size of the tumour (Hammarskjöld, 1934), the first intimation that it has taken place being the appearance of metastases in the lungs or elsewhere, thereby precluding the possibility of curative treatment.

It is perhaps permissible, in the event of a symptomless tumour being discovered accidentally by radiography, to withhold radical treatment if any other physical disability or an unfavourable mental reaction contraindicates it, provided that serial x-ray pictures demonstrate no tendency on the part of the tumour to grow. In all other cases, bearing in mind the limitations of medical treatment and having regard to the complications already enumerated, which may quite suddenly and without warning drastically alter the clinical picture, a surgical attempt to obtain a cure should be seriously contemplated and, in most instances, advised.

As a background for modern procedures it would not be unprofitable shortly to trace, historically, the development of surgery in this field and to sketch the evolution of a technique which is still developing.

Many of the earlier operations were undertaken in the absence of an accurate diagnosis. Poehn (1871) was the first to apply surgical principles when he introduced a trocar and cannula into a dermoid cyst for the evacuation of pus. The result is not stated. Kückmann, in 1874, by a similar procedure reduced the size of the sac and achieved an improvement by closing a bronchial fistula. Butlin (1883) in Holmes and Hulke's *System of Surgery* contributes the first record in English of a drainage operation on a mediastinal dermoid cyst, but the earliest complete and detailed account in the English language is an article by Godlee in 1889. He operated upon a young woman for a supposed "empyema" and the true nature of her illness was not disclosed until a rib had been resected and the cavity explored with the finger. Numerous operations were performed upon this patient with the object of removing the papillomatous processes that lay within the cyst and reducing the size of the cavity but, as Morris (1905) relates from a personal communication he received later from Godlee, the woman died of "pyaemia" four years after the first operation. Bastianelli (1893) lays claim to being the first surgeon completely to remove, in one stage, a dermoid cyst of the mediastinum. The operation was curative. Von Eiselsberg, operating on the patient in Türk's case (1903), achieved a similar success and in the same year Madelung (1903) cured his patient by radical surgery after rib resection and drainage had left a fistula. From then on, many attempts were made either to remove a tumour completely or, failing that, to remove it partially and marsupialise the remainder to the chest wall. A varying degree of success attended these exploits, some of which were performed in multiple stages and required supplementary thoracoplastic operations for their completion.

There can be hardly a doubt that from 1918, the practical experience gained during the years of the World War of 1914 to 1918, was put to good use. Thoracic surgery, as a separate branch, was born and the surgeon learned, after mastering the problem of the open pneumothorax with the assistance of an overpressure anaesthesia, that technical accomplishments, undreamed of hitherto, had only to be practised to be made effective. In these postwar years more than half the literature of the subject has been built up and in place of partial success or improvement can now be read accounts of radical cures. American workers have been most prolific in output, but this country has not lagged behind in originality for it was in 1914 that Morriston Davies effected almost a complete cure from a many stage attempt to deal with a teratoma, while Tudor Edwards, in 1926, reported three examples of the success that can follow radical surgery. A review of the literature, with particular reference to the results of surgery, has been undertaken on a

few occasions in the past, notably by Aurousseau (1924) and Howard Beye (1926).

From a study of the medical literature bearing on this subject there exists a choice of three possible procedures, leaving on one side aspiration of the contents of a cyst, a manoeuvre as deftly performed by the physician as by the surgeon and having only a palliative effect. The results of treatment along these three lines of approach in the hands of previous workers will now be considered.

1. *Rib resection and drainage:* It is apparent, from a study more especially of the earlier writings, that rib resection has been used either, mistakenly, in the treatment of an empyema or else as a last resort to lend aid to a patient in extremis. The results are bad. As the only method of treatment it has been employed on thirty-one occasions, of which thirteen patients were improved, fourteen died, and in four the result was not stated. Sometimes it has been used as a preliminary measure to more effective surgery later and, in this connexion, it serves not only a useful but a necessary purpose if the case demands it. Apart from this solitary indication, however, it has little to recommend it.

2. *Partial removal and marsupialisation:* It sometimes happens, when adhesion between the tumour and other organs is unusually firm, that partial removal is the only course open to the surgeon and is the makeshift result of an exploratory thoracotomy designed to remove the entire tumour. In fact, the operator should be prepared to accept this as a possible outcome of every exploratory thoracotomy in this disease, and should reason that it is wiser partially to remove and marsupialise a tumour successfully than to run an overwhelming risk of a major surgical disaster. Moreover, if the nature of the tumour and limited adhesions permit a radical operation but the condition of the patient causes anxiety, partial removal and marsupialisation do not preclude the possibility of a second attempt at a later date; thus, such an operation has often proved but the first step towards a multiple-stage complete removal of the tumour. When this operation is employed alone the results are slightly more gratifying than rib resection and drainage partly, no doubt, because the condition of the patient has allowed this more serious interference. Of fifteen patients so treated in the past, nine were regarded as improved, four died, while in one the result was not stated, and in one it was described as unsatisfactory. A large proportion of the tumour can be removed in this way and the dangers of increasing girth and subsequent infection largely banished from the future clinical picture. Yet the operation cannot be classed as radical in view of the theoretical possibility of malignancy supervening in that portion of the tumour that is left. There is, also, every likelihood of a persistent sinus permanently discharging secretion, although the fact that such a sinus can be made to heal has been demonstrated in Case 3.

3. *Complete excision of the tumour in one or more stages:* Complete excision is the ideal to be aimed at when surgical intervention has been decided upon, and in the hands of experienced men has given very satisfactory results. It has been attempted on sixty occasions; in fifty-three of these the tumour was removed and the patient cured, in four improvement resulted but a persistent fistula excluded admission into the former group, and three died. The group "cured" includes those patients in whom a small tag of tumour had to be left attached to an important organ provided the wound was firmly healed, no fistula had resulted, and no symptoms were complained of. Thus, Garre (1918), operating upon Naegeli's patient, left behind a small portion of the cyst wall that was attached to the left auricle and Moir (1936) had to sacrifice a similar portion tightly bound to the pericardium. Likewise, the pedicle that is occasionally encountered running from the sternum or mediastinum to the cyst often has to be ligatured, divided, and the proximal end disregarded. The risk of malignancy supervening in this minute fraction retained by the host can be considered infinitesimal.

The impressive figure of fifty-three patients cured out of sixty operations performed must be viewed in its right perspective and cannot legitimately be placed on a percentage basis. It is natural that the surgeon should regard a successful operation of this sort as a technical triumph worthy of publication and it may well be that many of the failures were never recorded because it was believed they lacked originality and value. Even with this reservation, however, the published experience of thoracic surgeons in all quarters of the globe in this disease has conclusively demonstrated the superior value of complete extirpation over all other procedures and, as this experience widened, engendering a correspondingly wider margin of operative safety, the belief that surgery should be preventive rather than curative in design swiftly gained ground. Thus, in 1924, Aurousseau wrote: *"Le traitement est essentiellement un traitement chirurgical ses indications sont formelles et il n'existe pas de contre indication."* Harrington's opinion was expressed in 1937 in these unminced words: "The only treatment that is effective for anterior mediastinal tumours is their complete surgical removal and this should be accomplished as soon as the diagnosis can be established, regardless of the severity of the symptoms." With such authoritative statements as these in mind and in the light of the published records, there will be little dispute as to what is the fundamental aim of surgery in this disease. There are, however, certain practical details, due observance of which are important if the patients' chances are to be accurately assessed and success is to be attained.

In the first place it is clear that the position of the tumour, as well as its size, must be taken into account when the prospects of surgery are being reviewed. They can be conveniently divided into the three

groups that were adopted by Aurousseau in 1924 following the plan propounded by Duval and Clerc (1921):

1. *Retrosternal and cervical:* Most of those that present in the neck are retrosternal or cervical. The removal of these tumours is comparatively easy and can often be accomplished through a collar incision as for a low goitre leaving the thoracic cage untouched. Sometimes, however, the sternum must be split or the sternoclavicular joint disarticulated in order to obtain adequate exposure.

2. *Retrosternal and thoracic:* In retrosternal and thoracic the tumour is completely concealed by the sternum and its removal is a little more difficult. A triangular flap or trap-door incision, as was first used by Kerr and Warfield, in 1928, has proved useful for this type.

3. *Lateral thoracic:* The designation lateral thoracic applies to tumours that take origin from the mediastinum and may indeed have preserved a central connexion, yet are seen to lie predominantly in one or the other side of the chest. Rarely, indeed, a tumour can extend a prolongation from the hilum and into the lung and may, therefore, to this extent, be regarded as intrapulmonary (J. E. H. Roberts, Personal communication). Removal may present a difficult problem and the approach can be either from in front or from behind. Harrington, from a wide personal experience, favours the posterior approach, while an anterior mediastinotomy is more popular in this country than in the U. S. A. The posterior approach gives adequate exposure even for the removal of the retrosternal and thoracic group.

A second factor that demands careful consideration in treatment is infection, and skilful handling of this complication will often ensure the success of an enterprise that will be doomed to failure if approached in more slipshod fashion. Heuer (1929) has propounded the axiom that infection must be controlled before a serious attempt to remove the tumour is undertaken. This applies to infection both in and outside of the tumour. Thus, a complicating empyema should be drained and the general condition of the patient improved before anything further is done. If it is the contents of the cyst that is pyogenic it is often advisable to devote the first stage of an operation to marsupialising the cyst wall to the exterior and draining the contents. At this stage, also, some degree of mobilisation of the tumour can be effected to make marsupialisation easier and to shorten the second and perhaps the last stage of the procedure. Heuer's experience, related earlier in this communication, of a secondary empyema and mediastinitis resulting from a spilling of the contents of a dermoid cyst into the extrapleural space gives pause for thought. However benign the contents of a cyst may seem to be, it should be regarded as potentially infective and treated accordingly. In those operations in which evacuation of a cyst is a necessary preliminary to removal such evacuation should be accomplished in a manner as aseptic as possible. It would not be pressing the point too

much to advocate that a trocar and cannula be inserted into the cyst, the contents evacuated by suction, and the perforation in the cyst closed with a purse-string suture similar to the invagination of the appendix stump into the caecum after an appendicectomy. In this connexion, also, it is pertinent to consider the respective merits of a transpleural approach to the tumour or the shelling out of the tumour without opening the pleural cavity. For a small tumour centrally placed, the latter course would seem preferable; however, if the element of infection is already present or is to be feared the transpleural approach is the better, partly because the pleural cavity can deal with infection, if it occurs, more satisfactorily than the extrapleural tissues and partly because an empyema can be more conveniently and easily drained than, say, a suppurative mediastinitis. In actual practice, if the cyst has attained a fair size and the lung is in any way encroached upon, the use of a transpleural approach is almost inevitable.

A third factor that has to be overcome if it is not to prevent the attainment of a radical cure is adhesion between the tumour and other vital organs. These adhesions can vary from thin filamentous bands capable of division by blunt dissection to a uniform dense fusion between the tumour and pericardium or pleura between which it is impossible to find any plane of cleavage. During life and before operation there is no means of gauging accurately the state of these adhesions. There are, however, three observations which, if properly appreciated, and particularly if found together, are suggestive of a close union between the tumour and pericardium covering the heart and great vessels. These are vigorous pulsation in the front of the chest that can often be both seen and felt, a persistent and sustained tachycardia in the absence of any other cause such as infection, and a right axis deviation of the electrocardiogram if heart disease can be excluded.

Finally, there remains for discussion the important questions of anaesthesia and aftercare. An overpressure anaesthetic with tracheal intubation, a development which has made a great contribution to the advancement of thoracic surgery, is indispensable in an operation of this type. One pleural cavity will probably be entered in any event and the danger of inadvertently opening the other is always present. In this contingency an overpressure apparatus is lifesaving (Robertson and Brown, 1929). Moreover, if the decision to close the chest without drainage has been taken, re-expansion of the lung can be assisted, and the convalescent period thereby shortened, by inflating the lung while the last few stitches are being inserted into the parietal pleura.

The care and attention required in the immediate postoperative period should be administered by those well versed and highly skilled in this specialised branch of major surgery. It is beyond the scope of this review to enlarge upon the details involved in this aftertreatment designed to secure painless rest for the patient, to enhance the per-

centage of oxygen in the air breathed, to counteract immediate and delayed shock by blood transfusion, to remove the effusion, sterile or infected, that collects in the pleural or dead space, and, lastly, to promote reinflation of lung and maximum respiratory function. They form the closing chapter and illustrate, with what has gone before, how the scientific and technical advances of recent years have simplified the diagnosis of this disease and placed the successful management of it in the hands of the thoracic team.

SUMMARY

1. A review is presented of dermoid cysts and teratomata of the mediastinum based upon a study of the world's literature and six examples that have been recorded for the first time in this communication.

2. After an historical introduction and an account of the six original cases, the clinical features, special investigations used in establishing the diagnosis, the differential diagnosis, complications, and treatment of this class of tumour are considered. The results of treatment are discussed.

3. In an appendix is given a list of references containing case reports from the first recorded example in 1827 until the end of 1939, during which period it has been computed that there are 245 cases on record. This figure does not include those described here.

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Appendix

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CLOSED INTRAPLEURAL PNEUMONOLYSIS

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INTRODUCTORY STATEMENT

THIS study deals primarily with the operative and postoperative complications and mechanical results of pneumonolysis and with early postoperative results of pneumothorax. It is based on my own experience as well as on data obtained from a series collected from the literature, which together with my series totals more than 7,929 operative stages on 7,157 tuberculous patients. In the course of this study the available American and English literature on closed intrapleural pneumonolysis published since Moore's[33] report of a collected series of 2,043 cases in 1934 was reviewed and essential data incorporated into Tables X, XI, and XII.

I agree with those who regard thoracoscopy and pneumonolysis as an integral part of a program of collapse by pneumothorax. It is my opinion that, as will be explained, only the technical results of the operation and complications attributable to it may be regarded as true results of the operation. The so-called clinical results embracing cavity and sputum status are, strictly speaking, the result of postoperative collapse by pneumothorax and not of pneumonolysis. Therefore, it is believed to be not premature to report the technical results, postoperative complications, and clinical course in my series, despite the fact that only six months have elapsed from the date of the last operation.

In Moore's collected series no mention of the preoperative duration of pneumothorax and of the extent of the pulmonary disease was

TABLE I

PREOPERATIVE STATUS

48 PATIENTS

Sex	Males	20
	Females	28
Age	Range	14 to 45
	Average	26
Race	Caucasian	23
	Noncaucasian	25
Pneumothorax	Unilateral	44
	Bilateral	4
Duration of pneumothorax (months)	Range	1 to 38
	Average	8
Extent pulmonary tuberculosis (N. T. A.)	Moderately advanced	11 (23%)
	Far advanced	37 (77%)

From the Olive View Sanatorium, Olive View, Calif.
Received for publication March 3, 1944.

TABLE II

HOMOLATERAL LUNG
(50 LUNGS)

Lung	Right		25
	Left		25
Infiltration	Exudative		36 (72%)
	Fibrotic		1
	Mixed		12 (28%)
	None		1
X-ray evidence of cavitation	Demonstrated		39 (78%)
	Not demonstrated		11 (22%)
Size of pulmonary cavities (cm.)	Range		1 to 7
	Average		2¼
	3 cm. or less		29 (74%)
	Over 3 cm.		10 (26%)
Number of cavities per lung	Range		1 to 5
	Average		1½
Known age of cavities (months)	Range		2 to 20 plus
	Average		6½ plus
Pleural effusion (excluding those occupying bottom of costophrenic angle)	Serous	Small	3
		Moderate	3 (12%)
	None		44 (88%)
Obliterative pleuritis (positive intrapleural pressures)	Present		3 (6%)
	Absent		47 (94%)

TABLE III

MISCELLANEOUS DATA

Contralateral lung	Entirely clear			6 (13%)
	Infiltration only (small or moderate)			29 (60%)
	Patent cavitation			11 (23%)
	Cavitation controlled by pneumothorax			2 (4%)
Tubercle bacilli in sputum or gastric washings	Demonstrated	Concentration	28	36 (75%)
		Culture only	8	
	Not demonstrated (but previously demonstrable)	Concentration only	3	12 (25%)
		Culture	6	
	Never demonstrated (Mantoux positive)		3	
Bronchoscopic findings (main and lobar bronchi)	Erythema			4 (14%)
	Ulceration			0
	Stenosis			0
	Negative			24 (86%)
	Total bronchoscoped			28 (100%)
Temperature	Febrile (subacute serous effusion)			1
	Afebrile			49
Homolateral phrenic paralysis				3

made.[33] In my collected series the preoperative duration of pneumothorax was found reported for about two-fifths of the patients and it ranged from one to fifteen months; the extent of pulmonary disease was found reported for only about one-fifth of the patients and its incidence was as follows: minimal 6 per cent, moderately advanced 33 per cent, far advanced 61 per cent.

No data regarding the sputum status and the incidence of contralateral or extraparenchymal source of positive sputum were presented with Moore's collected series.[33] In my collected series the sputum status was found reported for about one-half of the patients and was as follows: positive 83.5 per cent, negative 16 per cent, unknown 0.5 per cent. The incidence of contralateral or extraparenchymal source of positive sputum was found reported for about one-eighth of the patients in my collected series and it ranged from 13 to 83 per cent.

THORACOSCOPY AND PNEUMONOLYSIS

This study includes all pneumonolyses, consecutive and unselected, done by me at the Olive View Sanatorium between September, 1941, and October, 1942. They totaled 55 operations on 50 lungs of 48 patients; upon 5 patients the operation was done in two stages. In addition, there were 4 thoracoscopies without pneumonolysis done and these were included in a study already reported.[20]

In 1934, Moore[33] published his study of a series consisting of 2,043 cases collected from the literature of 1924 to 1932, inclusive; the number of operative stages was not stated. My collected series consists of 5,114 patients subjected to more than 5,886 operative stages done between the years of 1927 and 1942, and reported in the literature of 1933 to 1943, inclusive; in this series the year of operation was indicated for about two-thirds and the number of operative stages for about four-fifths of the total number of patients.

As a rule I found more adhesions thoracoscopically than expected from the study of the roentgenograms, including stereoscopic films, supporting earlier contentions that thoracoscopy and not roentgenography is the only accurate method of determining the exact number, character, and feasibility of freeing adhesions.[20] In the great majority of cases the visceral attachment of adhesions freed was on the upper lobe and the parietal attachment on the upper posterior chest wall.

In Moore's collected series galvanocautery was employed by 83 per cent, electrosurgery by 7 per cent, and the combination of the two methods by 10 per cent of those reporting.[33] The type of current used in my collected series was indicated for about three-fourths of the patients: galvanocautery 41 per cent, electrosurgery 26 per cent, combination of the two methods 3 per cent, and a succession of different methods 30 per cent. The following synonymous terms were encountered in the literature reviewed in connection with the description of

type of current employed in pneumonolysis: for galvanocautery: cautery, actual cautery, electrocautery; for electrosurgery: high frequency current, endothermy, surgical diathermy. The two-cannula technique and galvanocautery were employed in my series.

The patients were kept in the surgical wards for a period varying from one to several weeks after I had operated upon them. They were fluoroscoped on the first postoperative day and as indicated thereafter. About one-half of the patients were under my own care while in the surgical wards; upon return to the medical wards these patients came under the care of the medical ward physicians.

TABLE IV

Duration of operation (min.)	Range	20 to 110 min.
	Average	60 min.
	30 min. or less	10 operations (18%)
	60 min. or less	36 operations (65%)
	Over 60 min.	19 operations (35%)

No mention of the duration of the operations was made in Moore's collected series,[33] in my collected series this was found reported for about one-fifth of the operations and it ranged from a few to ninety minutes with a maximum average of sixty-five minutes.

TABLE V

Type of adhesion operated upon	Strings	17 (10%)
	Cords	57 (34%)
	Bands	92 (56%)
	Total	166 (100%)
Number of adhesions operated on (per patient)	Range	1 to 9
	Average	3

In anticipation of a correlation between the type of operation and complications and results, I classified all operations as follows: complete pneumonolysis is one involving complete freeing of all adhesions attached to the diseased pulmonary lobe; incomplete is one involving

TABLE VI

Type of operation	Complete	30 (55%)
	Incomplete	8 (15%)
	Partial	17 (30%)

TABLE VII

POSTOPERATIVE INSTITUTIONAL FOLLOW-UP
(AS OF APRIL 1, 1943)

Discharged from Olive View Sanatorium	15 (31%)
Still at Olive View Sanatorium	33 (69%)
Died at Olive View Sanatorium	0

complete freeing of only some of the adhesions attached to the diseased lobe; and finally, partial pneumonolysis is one involving partial freeing of all or some of the adhesions to the diseased lobe.

The postoperative stay at the Sanatorium ranged from one week to eighteen months and averaged eight and one-half months. This is shown in greater detail in Table VIII.

TABLE VIII

LENGTH OF STAY AT SANATORIUM	NO. OF LUNGS	PER CENT
Less than 1 mo.	1	2
Less than 3 mo.	5	10
Less than 6 mo.	11	22
Less than 10 mo.	29	58
More than 10 mo.	21	42
Total	50	100

In 5 of the patients still at the Sanatorium, pneumothorax had been supplemented by phrenic nerve interruption, and in 9 patients it was abandoned as ineffective three weeks to eleven months postoperatively (average of four months) and a thoracoplasty substituted or planned on. Disease in the contralateral lung was treated as indicated. At the time of this communication, only one patient is clinically worse than she was at the time of operation which was complete and free of complications, but due to ulcerative and stenotic tuberculous bronchitis the pulmonary cavity is still patent, the sputum positive, and she is febrile. Since the operation 6 patients were bronchoscoped for the first time and 5 others were rebronchoscoped; 2 of the former and 1 of the latter were found to have bronchial ulceration.

In Moore's collected series the duration of the postoperative period of observation was not specified except for the statement that only immediate results were given and that Unverricht was the only one to report results following re-expansion.[33] In my collected series the length of the postoperative period of observation was found reported only for about one-half of the patients and it ranged from one to sixty months; Jones was the only one to report results following re-expansion in part of his series.[29]

POSTOPERATIVE COMPLICATIONS

For the sake of completeness all complications, including fever and small effusions, which occurred during the entire postoperative stay at the Sanatorium regardless of whether attributable to the operation or to coexisting tuberculosis and pneumothorax were included (Table IX). Only complications which were not present preoperatively were included in my own series; wherever sufficient data were available the same was done in my collected series.

TABLE IX

COMPARISON OF THE INCIDENCE OF POSTOPERATIVE COMPLICATIONS ATTRIBUTABLE AND THOSE NOT ATTRIBUTABLE TO PNEUMONOLYSIS

55 Operative Stages on 50 Lungs of 48 Patients at Olive View Sanatorium From September, 1941, to October, 1942

COMPLICATIONS	INCIDENCE							
	BOTH ATTRIBUTABLE AND NONATTRIBUTABLE TO OPERATION				NONATTRIBUTABLE TO OPERATION		ATTRIBUTABLE TO OPERATION[1]	
	TOTAL		WITHIN 1ST 4 WK.	AFTER 1ST 4 WK.				
	NO.	PER CENT			NO.	PER CENT	NO.	PER CENT
Entirely absent	31	56[2]	--	--	--		--	
Present	24	44[2]	--	--	--		--	
Fever	24	44[2]	24	0	0		24	44[2]
Intrapleural hemorrhage	1	1.8	1	0	0		1	1.8
Severe subcutaneous emphysema	1	1.8	1	0	0		5	9
Serous effusion	6	11	5	1[3]	1	2[3]	1	1.8
Spontaneous pneumothorax	2	3.6[4]	0	2[4]	2	3.6[4]	0	
Extension of pulmonary Tb.	2	3.6	0	2[5]	2	3.6[5]	0	
Obliterative pleuritis	1	1.8[3]	0	1[3]	1	1.8[3]	0	
Bronchopleural and pleurocutaneous fistula; pure tuberculous, pyogenic and mixed empyemas; loss of pneumothorax, air embolism, shock, nerve injury, secondary perforation of lung; death	0		0	0	0		0	

[1]All occurred within the first four postoperative weeks.

[2]If the 18 instances of insignificant fever occurring alone were disregarded the incidence of freedom from complications would rise to 89 per cent and the incidence of fever would fall to 11 per cent.

[3]Eight months postoperatively.

[4]Three and five months postoperatively in the same patient.

[5]Three months postoperatively.

In a recent study[21] criteria of attributability of postoperative complications to the operation were fully discussed and it was suggested that all complications occurring within the first four postoperative weeks, as well as those occurring later but pathogenetically related to the operation, be regarded as attributable to the operation rather than to the coexisting tuberculosis and pneumothorax; these criteria have been adhered to in this study. The only complications attributable to the operation that occurred in my own series were fever, intrapleural hemorrhage, subcutaneous emphysema, and serous effusion and none of these were appreciably detrimental to the patients involved (Table IX).

In my own as well as the collected series the incidence of complications except obliterative pleuritis, loss of pneumothorax space, and death was calculated on the basis of the number of operations, where known, rather than the number of patients (Table X). Wherever sufficient data were found in the collected series regarding relationship between postoperative complications and the operation, only those attributable to the operation were included in the tables, otherwise all were included.

TABLE X

INCIDENCE OF COMPLICATIONS ATTRIBUTABLE TO PNEUMONOLYSIS

More Than 7,929 Operative Stages on 7,157 Patients From 1924 to 1943 Inclusive

COMPLICATIONS	INCIDENCE (IN TERMS OF PER CENT) IN SERIES COLLECTED BY MOORE, 1924-1932 (2,043 PATIENTS)		GOORWITCH, 1933-1943 (5,114 PATIENTS)[1]		GOORWITCH—OWN SERIES, 1941-1942 (48 PATIENTS)	DATA AS TO INCIDENCE IN GOORWITCH COLLECTED SERIES WERE FOUND REPORTED ONLY FOR ABOUT
	RANGE	AVERAGE	RANGE	AVERAGE		
Entirely absent	?	?	27-89	49	89	
Present	?	?	11-73	51	11	1/6 of operations
Prolonged fever	?	?	0-13	7	3.6	1/4 of operations
Intrapleural hemorrhage						
Small	0-100[2]	0.85[2]	0-12	3.30	0	1/2 of operations
Large or serious	0-100[2]	0.80[2]	0-13	1.70	1.8	2/3 of operations
Severe surgical emphysema	?	?	0-20	2.60	1.8	2/5 of operations
Spontaneous pneumothorax	?	?	0-12	2.30	0	2/5 of operations
Bronchopleural fistula	?	?	0- 8	2.50	0	1/2 of operations
Serous pleural effusion						
Small	0- 93[3]	25.50[3]	0-55	16	5.4	1/4 of operations
Large	0- 33[4]	8.80[4]	0-27	9.50	3.6	1/3 of operations
Empyema						
Pure tuberculous	0- 8	2.20	0-24[5]	3	0	2/3 of operations
Pyogenic	?	?	0- 6	0.24	0	1/2 of operations
Mixed tuberculous	0- 23	1.80	0- 5	1	0	1/2 of operations
Obliterative pleuritis	?	?	0-11	7	0	1/4 of patients
Loss of pneumothorax	0- 4	0.29	0-10	3	0	1/6 of patients
Air embolism	0- 0.04	0.04	0- 1.1	0.06	0	1/6 of operations
Pleurocutaneous fistula	0- 8	0.14	0- 2	0.35	0	1/7 of operations
Secondary perforation	0- 4	0.39	0- 1.3	0.70	0	1/12 of operations
Extension of pulmonary tuberculosis	?	?	0- 6	1.30	0	1/6 of operations
Nerve injury	?	0.04	0	0	0	Very rarely
Shock	?	0.04	0- 2	0.15	0	
Death	0-100[6]	1.08[6]	0- 6	1.18	0	9/10 of patients

[1]Including Goorwitch's own series.
[2]Reported only for 1,883 cases.
[3]Reported only for 1,807 cases.
[4]Reported only for 1,875 cases.
[5]Turner reported an incidence of 24 per cent by including all those cloudy and purulent any time postoperatively;[49] 0 to 10 per cent is the more correct range.
[6]Reported only for 1,850 cases.

Fever.—Unless high and prolonged or accompanied by other significant complications, fever is not a complication in the strict sense of the word, but is considered here, as in previous studies,[20, 21] only for the sake of completeness. Temperature of 100° F. and over was again arbitrarily chosen to designate fever of some clinical significance in intrapleural surgical intervention.

Accordingly, in my own series fever was present following 24, or 44 per cent, operations; its onset was on the day of operation or on the first postoperative day and it lasted continuously from one day to three weeks and an average of four days. In 75 per cent of these patients the duration of fever was three days or less, in 92 per cent

one week or less, and in the remaining 8 per cent over 1 week (maximum of three weeks). Maximum* fever ranged from 100 to 102° F. and averaged 100.4° F. Following 15 operations, maximum fever was 100, following 7 operations 101, and following 2 operations 102° F. Thus, fever was not a serious complication, as among those febrile it did not exceed 100° F. in 36 per cent, was the only complication in 75 per cent, and lasted one week or less in 92 per cent.

In his collected series, Moore[33] did not mention fever among the postoperative complications. In my collected series the incidence of prolonged fever in one-fourth of the operations for which it was reported was 7 per cent. In my own series the incidence of prolonged fever (exceeding 100° F. and lasting over one week) was 3.6 per cent.

Intrapleural Hemorrhage.—I assume that loss of up to two ounces of blood, either from trocar wounds or cauterized adhesions, should not be regarded as a hemorrhage.[21] No criteria of what constitutes a small hemorrhage were found in the literature reviewed. If transient, small intrapleural hemorrhage is of no clinical significance. Large intrapleural hemorrhage is a fairly rare but, depending on its source, a most dangerous complication. In my single case of this complication the approach to the adhesions in the extreme apex was exceptionally difficult and more than two trocar punctures were made; slight oozing from one of the trocar wounds was noted during the operation but was thought to be of no importance. No bleeding from the released adhesions was noted and the patient left the operating room in excellent condition; however, during the first postoperative week a total of about 500 c.c. of at first sanguineous and later serosanguineous fluid was aspirated. The source of hemorrhage must have been an intercostal vein which was traumatized by the trocar and which continued to ooze after the withdrawal of the cannula.

In Moore's collected series one of the 31 hemorrhages proved to be fatal; it was described as small but was responsible for one of the 19 deaths attributable to the operation.[33] In my collected series 8 of the 159 hemorrhages proved to be fatal, thus accounting for 8 of the 59 deaths attributable to the operation; they were described as large (Table XI).

Although intercostal vessels constitute the most frequent source of intrapleural hemorrhage and even death is known to have resulted from uncontrollable hemorrhage from an intercostal artery, massive hemorrhage from injury to the great mediastinal vessels or the lung itself is by far the more serious. I have personal knowledge of three instances of operative injury to the mediastinal vessels with a rapidly fatal outcome despite a thoracotomy in one of them. Only infrequently was the source of hemorrhage stated in the literature reviewed.

*Fractions of a degree were eliminated by substituting the nearest whole number; thus 100.4 was recorded as 100° F. and 100.6 as 101° F.

TABLE XI

CAUSES OF DEATH ATTRIBUTABLE TO PNEUMONOLYSIS

CAUSES OF DEATH	SERIES COLLECTED BY	
	MOORE* (1924-1932)	GOORWITCH† INCLUDING HIS OWN SERIES (1933-1943)
Spontaneous pneumothorax	?	5
Bronchopleural fistula	?	24
Empyemas		
Pure tuberculous	?	1
Pyogenic	?	2
Mixed tuberculous	"majority"	5
Intrapleural hemorrhage	1	8
Air embolism	1	1
Extension of pulmonary disease	?	2
Cardiorespiratory decompensation	?	1
Unspecified	?	4
Total mortality	19 (1.08%)	53 (1.18%)

*1,850 cases.

†5,114 cases, but fatality statistics found reported only for about nine-tenths of the series.

Moore[33] stated that nearly all of the reported hemorrhages occurred with the use of the cautery, but when it is realized that 83 per cent of those reporting employed the cautery it will appear that the type of current used was not the deciding factor.

Surgical Emphysema.—Mild subcutaneous emphysema localized to the chest wall about the trocar wounds is common; it is not clinically important and strictly speaking is not a complication. In my own series there was one instance of severe subcutaneous emphysema in a patient with extensive pulmonary disease and a severe cough which was not controlled properly; loss of pneumothorax did not result.

Spontaneous Pneumothorax.—Spontaneous pneumothorax should be regarded as a serious complication as it may be followed by a bronchopleural fistula and a mixed tuberculous empyema. In my collected series 9 per cent of all deaths attributable to the operation resulted from this complication (Table XI). In my own series spontaneous pneumothorax not attributable to the operation occurred twice in the same patient three and five months postoperatively; it was relieved by simple aspiration of air but was finally abandoned when seven months postoperatively the 7 cm. cavity was still patent in spite of complete and uneventful pneumonolysis.

Bronchopleural Fistula.—The danger of the complication of bronchopleural fistula when clinically demonstrable is exceeded only by massive intrapleural hemorrhage from the great mediastinal vessels. No mention of this complication was made by Moore,[33] who probably included it in the mixed tuberculous empyema group of his collected series.

When clinically demonstrable a bronchopleural fistula is almost always accompanied or followed by mixed tuberculous empyema sug-

gesting that the source of the secondary infection is in the traumatized or sloughing lung. The incidence of this dreadful complication could undoubtedly be reduced if Newton's[34] ably presented concept of releasing as opposed to cutting, dividing, or severing adhesions were more fully appreciated and if adhesions only questionably operable as determined thoracoscopically were left alone. The opening statement in the preceding paragraph is amply supported by the fact that in my collected series about two-fifths of these complications proved fatal and a little less than one-half of all deaths attributable to the operation resulted from this complication (Table XI).

Pleural Effusions.—Most unoperated pneumothoraces have fluid at one time or another. Head is quoted by Moore[33] as having stated that following pneumonolysis tuberculous effusions were twice as common as in unoperated pneumothoraces; this must have been true two decades ago. In Moore's collected series the incidence of small and large pleural effusions was about 34 per cent,[33] in my collected series 25.5 per cent, and in my own series only 9 per cent.

Prominent in the more recent literature was evidence that pneumonolysis was not an important factor in the production of pleural effusions and that it certainly did not add materially to the incidence of pleural effusions occurring commonly with pneumothorax alone. In fact, purulent fluids and large serous effusions are believed by these workers to be less frequent following pneumonolysis than in unoperated pneumothoraces restricted by adhesions.[11, 12, 21, 29]

Pure Tuberculous Empyema.—Both purulent and large serous effusions complicating induced pneumothorax and closed intrapleural pneumonolysis are believed to originate in spontaneous or operative ulceration of pleural or subpleural tuberculous foci.[19] As already stated, the more recent reports indicate that following closed intrapleural pneumonolysis the incidence of empyema is no greater than in unoperated pneumothoraces.[11, 12, 21, 29]

In my collected series death from empyema occurred in only 1 of the 114 patients with this complication; in the 1 patient in my own series who was febrile at the time of the operation because of a subacute serous effusion a small amount of clear fluid persisted postoperatively and after many months of neglect to aspirate was found to have become purulent.

Mixed Tuberculous Empyema.—As previously stated, mixed tuberculous empyema is a very serious and fairly constant sequel to bronchopleural fistula and the two follow spontaneous or operative trauma to tuberculous lung tissue. In Moore's collected series all mixed tuberculous empyemas resulted from perforation of lung or opening into a pulmonary cavity and about one-third of them died; this complication was responsible for the majority of all deaths in his series.[33] In my collected series bronchopleural fistula or tuberculous, pyogenic or mixed

tuberculous empyema, all of which represent pulmonary trauma associated with pleural infection, proved fatal in one-sixth of the cases and were responsible for a majority of all deaths. (Table XI).

Pyogenic Empyema.—It is generally thought that external contamination, as by unsterile instruments, is much less frequently responsible for this complication than operative trauma to lung tissue. Its outcome was fatal in 2 of the 7 instances in my collected series (Table XI).

Obliterative Pleuritis.—By the term obliterative pleuritis is meant a gradual restriction of the pleural space through creeping out of the lung edges accompanied by a rise of intrapleural pressures and decreased demand for air refills. Following pneumonolysis the incidence of this complication is said to be definitely higher than in unoperated pneumothoraces.[29] The only instance of obliterative pleuritis in my series developed eight months postoperatively without loss of space and was not attributed to the operation.

Other Less Common Complications.—Less common complications were found reported but rarely in my collected series and were not encountered in my own series. They include loss of pneumothorax space, air embolism, pleurocutaneous fistula, secondary perforation of the lung, shock, nerve injury, and extension of pulmonary disease.

As an early postoperative complication, loss of pneumothorax space is generally employed to designate loss of pneumothorax from rapid loss of air through severe and uncontrollable surgical emphysema and not through gradual obliterative pleuritis. Air embolism was uniformly fatal. In Moore's collected series an effusion was present at the time of operation in those cases which became complicated by pleurocutaneous fistula. He regarded perforation of lung secondary only if it occurred more than six weeks postoperatively.[33]

Operative and Postoperative Deaths.—In Moore's collected series the majority of the 19 deaths attributable to the operation was ascribed to mixed tuberculous empyema resulting from perforation of the lung or opening into pulmonary cavities within the first six postoperative weeks. Only 1 fatality was ascribed to air embolism and 1 to a small intrapleural hemorrhage despite the fact that there were 15 serious hemorrhages; the causes of the remaining deaths were not given.[33]

In my collected series also the majority of the 53 deaths attributable to the operation resulted from lung trauma and infection; second in frequency was intrapleural hemorrhage and the remaining deaths were due to less common and unspecified causes. Thus, operative trauma to lung with resulting infection of the pleural cavity is by far the most common cause of death attributable to the operation and is probably due more frequently to defective judgment and failure to recognize inoperable adhesions than to a pure accident. On the other hand, intrapleural hemorrhage, the second most common cause of

death, is believed to result more frequently from a purely accidental injury to a vascular structure than from defective surgical judgment.

In Moore's collected series in which 83 per cent of those reporting employed galvanocautery, the great majority of deaths also followed the use of galvanocautery.[33] In my collected series there was likewise no relationship between the type of current used and the incidence of fatality, which suggests that the type of current is not the determining factor but that surgical judgment is.

TECHNICAL RESULTS OF CLOSED INTRAPLEURAL PNEUMONOLYSIS

Moore classified the results in his collected series of 1,850 cases as technically successful in 71 per cent and technically unsuccessful in 29 per cent.[33] In my collected series of 5,114 patients these terms were found employed for about one-sixth of the patients and the incidence of technical success ranged from 72 to 100 per cent and averaged 90 per cent. Andrews pointed out that this terminology was too vague and unless explained left the reader confused as to the extent of the operation;[3] partial freeing of an adhesion may be regarded by one operator as technically successful if in his opinion sufficient freeing was done to produce clinical success, whereas another operator may classify such an operation as technically unsuccessful because regardless of the clinical results anticipated it failed to achieve complete freeing of the lung.

I agree with those who prefer the terms complete and incomplete pneumonolysis (the latter includes my incomplete and partial pneumonolysis) as almost self-explanatory. This term was found employed for about one-third of the patients in my collected series and among these the incidence of complete operation ranged from 30 to 89 per cent and averaged 52 per cent; in my own series 55 per cent were complete and 45 per cent incomplete and partial. The fact that in my collected series the incidence of clinical success, 73 per cent, was about midway between the incidence of complete operation, 52 per cent, and that of technical success, 90 per cent, confirms the actual difference between the relative value of the terms complete pneumonolysis and technically successful pneumonolysis.

POSTOPERATIVE CLINICAL RESULTS OF PNEUMOTHORAX

There is general agreement as to the criteria of clinical success following pneumonolysis: satisfactory collapse with cavity closure, sputum conversion, and a minimum of postoperative complications; with the exception of the last mentioned the criteria, of course, are those of successful pneumothorax. In regard to the length of postoperative period to be allowed before a fair estimation of clinical results can be made, there is no unanimity of opinion. Drash[13] stated that the results of the operation were immediate and did not include end results of pneumothorax; Matson[31] added that the results of pneumonolysis were only remotely related to the end results of pneumothorax. Moore[33] went

further to state that in the final analysis the end results of pneumothorax should be the real test of the operation. Unverricht, quoted by Moore,[33] and Jones[29] were the only two in the literature reviewed to report late results of pneumonolysis evaluated on the basis of end results of pneumothorax, that is, following voluntary discontinuance of pneumothorax. The latter worker suggested that results of pneumonolysis cannot be based on the success or failure to divide adhesions but must be evaluated by extensive work-up and complete follow-up data.[29] And finally Andrews[3] put in the much-needed plea for standardization of the time for classification of results, suggesting one year postoperatively or when the pneumothorax is discontinued.

Moore[33] reported the immediate results in his collected series of 1,850 cases as clinically successful in 75 per cent and clinically unsuccessful in 25 per cent; in my collected series of 5,114 patients clinical results of pneumonolysis were found reported for about one-half of the patients and were based on observation ranging from one month to five years postoperatively. The incidence of clinical success ranged from 44 to 96 per cent and averaged 73 per cent. Two authors classified their patients as in good health, in fair health, etc.[6, 7, 43]

Moore[33] did not mention the incidence of cavity closure and sputum conversion separately in his collected series. Wherever sufficient data were found in the articles reviewed by me the incidence of cavity closure and sputum conversion, as given in Table XII, was based on the number of patients with preopertaive x-ray evidence of patent cavitation in the lung operated on and with positive sputum, respectively, rather than on the total number of patients operated on. Obviously, unless the source of positive sputum is localized in the parenchyma of the lung operated on, the apparent incidence of sputum conversion obtained will be lower than the actual one.

I regard technical alterations in the character of the collapse and complications attributable to the operation as the only direct results of pneumonolysis; as will be explained, what is regarded in the literature as clinical results of pneumonolysis I consider as results of pneumothorax following pneumonolysis. This is the reason for the

*Explanation of Table XII, p. 236-239.

Operative technique: G, galvanocautery. E, electrosurgery. C, combination of galvanocautery and electrosurgery in the same operation. B, experience with both types of currents in different operations.

National Tuberculosis Association (N. T. A.) classifications: M., minimal pulmonary tuberculosis. M. A., moderately advanced pulmonary tuberculosis. F. A., far advanced pulmonary tuberculosis.

Thompson and Greenberg: Two separate series reported; the upper figures in the fraction-like expressions refer to a series done in four New York City hospitals and the lower figures to a series done in a municipal sanatorium in N. Y. state.

Carp and Kornblith: Average postoperative period of observation was ten months.

Olive View Sanatorium series reported by Goorwitch: In calculating the incidence of complete freedom from complications fever of 100° F. and over as well as all complications attributable and nonattributable to the operation were regarded as complications.

Goorwitch's own series: If insignificant fever occurring alone postoperatively were disregarded the incidence of complete freedom from complications would rise to 89 per cent.

Miscellaneous: Important but infrequently mentioned data.

AUTHOR AND DATE OF PUBLICATION	OPERATIVE TECHNIQUE	NUMBER OF PATIENTS	PREOPERATIVE STATUS				OPERATIVE AND POSTOPERATIVE COMPLICATIONS (%)								
			N. T. A. CLASSIFICATION (%)		SPUTUM (%)		INTRAPLEURAL HEMORRHAGE		SPONTANEOUS PNEUMOTHORAX	BRONCHOPLEURAL FISTULA	SEROUS EFFUSIONS		EMPYEMA		
			M.A.	F.A.	+	−	SMALL	LARGE OR SERIOUS			SMALL	LARGE	PURE TUBERCULOUS	PYOGENIC	MIXED TUBERCULOUS
Moore's collected series, 1934 (1924-1932)	G 83% E 7% C 10%	2,043	?	?	?	?	0.77	0.73	1.8	1.8	23	8	2.2	?	1.8
Stivers	C	20	?	?	?	?	?	?	?	?	?	?	?	?	?
Peters & Cornish	G	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Janes (1933)	G	14	43	57	80	20	0	7	?	?	0	14	?	0	0
Drash & Shelton	E	34	?	?	70	30	3	0	?	?	?	3	0	0	0
Matson	G 55% E 45%	249	?	?	98	2	8		0	1.3	20		13		
Randolph (1934)	G	59	?	?	?	?	5		5	0	?	?	5	0	0
Chandler	G 25% E 32% C 43%	89	0	100	?	?	?	13	4	?	?	22	2.7	0.9	2.7
Forsee	E	17	?	?	?	?	0	0	12	?	18		6	6	0
Washburn (1935)	G E	100	50	44	77	20	5	1	0	1	47	5	6	0	1
Andrews	E	22	?	?	100	0	8		?	?	?	?	4	?	?
Drash & Nicholls	?	122	?	Many	65	35	1.5	0.8	?	?	?	?	0	0	0
Dufault & Laroche	E	138	60	30	?	?	12	5	?	6	?	?	2.6	0	5
Peters & Cornish	E G	88	?	?	?	?	?	2.3	7	1.1	27		?	?	?
Coryllos (1936)	G	124	?	?	100	0	?	?	?	?	?	?	?	?	?
Anderson & Alexander	G	87	?	?	?	?	0	0	?	1.1	29	8	5	0	2.3
Chandler	G E	68	?	?	?	?	1	0	?	?	20	17	0	?	?
Powers (1937)	G	48	19	81	100	0	?	0	?	4	46	27	6	2	?
Christiansen	G	74	?	?	?	?	?	?	?	4	?	?	?	?	?
Drash	E	211	?	?	?	?	0.8	0.4	?	?	6		0.4	0	0
Rabinowitz & Rogers (1938)	E	54	?	?	100	0	?	0	?	?	7		2	0	0
Smart	G 48% C 52%	42	?	?	76	24	?	0	0	0	20	11	2	0	0
Edwards & Lynn	?	206	42	50	?	?	2.6	0.4	?	2.6	8	24			
Andrews	E	124	?	?	78	22	2.1	0	2.1	?	?	9	5	0	0.7
Jarvis	?	33	?	?	?	?	?	3	?	?	?	?	?	?	?
Jones, H. A.	E 48% G 52%	98	?	?	93	7	?	0	?	?	?	10	4	1	0
Matson	E 60% G 40%	350	?	?	90	10	1.6		1.6	3.8	3.9		2.8	?	?

XII

PNEUMONOLYSIS (1924-1943)*

OPERATIVE RESULTS (%)												
		CAVITY		SPUTUM		PNEUMONOLYSIS						
								TECHNICALLY		CLINICALLY		
LOSS OF PNEUMOTHORAX SPACE	DEATH	CLOSED	PATENT	CONVERTED TO NEGATIVE	UNCONVERTED	COMPLETE	INCOMPLETE	SUCCESSFUL	UNSUCCESSFUL	SUCCESSFUL	UNSUCCESSFUL	MISCELLANEOUS
0.29	1.08	?	?	?	?	?	?	71	29	75	25	Results for 1,850 cases; air embolism, shock and nerve injury each 0.04%; pleurocutaneous fistula 0.14%; secondary perforation 0.39%
?	?	?	?	?	?	85	15	–	–	?	?	Average operative time 40 min.
?	?	?	?	?	?	75	25	–	–	?	?	
?	0	?	?	64	36	50	50	–	–	?	?	Average preoperative age of pneumothorax 15 mo.
?	0	?	?	53	47	85	15	–	–	89	11	Results only for 27 cases
?	0	?	?	68	32	62	38	–	–	69	31	No air embolism or shock
?	?	63	37	?	?	?	?	?	?	51	49	No secondary perforation
?	3.4	?	?	?	?	55	45	–	–	?	?	Average operative time 40 min.; good health 53%; fair health or less 47%
6	6	76	?	?	?	?	?	82	18	?	?	Extension of T.b. 6%
4	2	?	?	71	29	47	53	–	–	?	?	Average preoperative age of pneumothorax 6 mo.; complete absence of complications 28%; pleurocutaneous fistula 2%
?	?	?	?	?	?	?	?	?	?	60	40	Extension of T.b. 4%
?	0	74	26	95	5	?	?	?	?	91	9	Average preoperative age of pneumothorax 6 mo.
7	6.5	71	29	?	?	?	?	72	28	60	40	Average operative time 44 min.
?	1.1	78	22	?	?	?	?	?	?	78	22	Air embolism 1.1%
?	?	?	?	56	44	?	?	100	0	?	?	Contralateral source T.b. 32%
1.1	2.3	63	37	?	?	47	53	–	–	?	?	Average preoperative age of pneumothorax 8½ mo.; pleurocutaneous fistula 1.1%
?	?	?	?	?	?	46	54	–	–	?	?	Good health 68%; fair health or less 32%
2	2	?	?	85	15	89	11	–	–	85	15	Average preoperative age pneumothorax 4½ mo.; shock 2%
?	4	?	?	85	15	?	?	?	?	85	15	Extension of T.b. 4%
0.4	0	75	25	93	7	?	?	?	?	86	14	Preoperative age of pneumothorax 4+ mo.; secondary perforation 1.3%; no air embolism or extension of T.b.
0	0	67	33	67	33	?	?	?	?	67	33	No nerve injury or pleurocutaneous fistula
?	2	?	?	?	?	50	50	–	–	?	?	Good health 64%; fair health or less 36%
10	?	44	?	?	?	38	62	–	–	44	56	Preoperative age of pneumothorax 2-9 mo.; shock 0.4%
?	1.6	?	?	65	35	64	36	–	–	65	35	Average preoperative age of pneumothorax 5 mo.; average operative time 45 min.
?	3	?	?	?	?	?	?	?	?	?	?	
?	1	83	17	83	17	?	?	85	15	83	17	
?	0	?	?	66	34	?	?	?	?	70	30	Complications for electrosurgery; no shock or embolism

AUTHOR AND DATE OF PUBLICATION	OPERATIVE TECHNIQUE	NUMBER OF PATIENTS	PREOPERATIVE STATUS				OPERATIVE AND POSTOPERATIVE COMPLICATIONS (%								
			N. T. A. CLASSIFICATION (%)		SPUTUM (%)		INTRAPLEURAL HEMORRHAGE		SPONTANEOUS PNEUMOTHORAX	BRONCHOPLEURAL FISTULA	SEROUS EFFUSIONS		EMPYEMA		
			M.A.	F.A.	+	−	SMALL	LARGE OR SERIOUS			SMALL	LARGE	PURE TUBERCULOUS	PYOGENIC	MIXED TUBERCULOUS
Phillips & Knoepp	?	26	?	?	?	?	?	?	4	?	?	?	?	?	?
Scarborough	G	77	?	?	?	?	3	0	?	0	7		0	1	0
Turner (1939)	E	59	?	?	?	?	?	0	?	8	?	8	24	?	?
Grimes	?	19	?	?	?	?	Few	5	?	?	10		10	?	?
Newton	E	146	?	44	75	25	0	0	?	0	12	5	2	0	0
Stemmerman & Tchertkoff	?	126	?	Majority	100	0	0	0	2.4	5	?	?	2.4	0	5
Stocklen & Greene	?	833	?	?	?	?	?	?	?	?	?	?	?	?	?
Wollaston (1940)	G	200	?	?	78	22	11	1.5	?	0.5	?	13	2	0	0
Black	?	69	13	84	80	20	?	1.1	?	?	Few		1.1	?	?
Hoffman & Brantigan	G	109	?	?	?	?	1	0	2	?	?	?	5	1	2
McCullough & Chapman	G	111	?	?	100	?	0	1.8	0.8	0		?	6	?	0
Thompson & Greenberg (1941)	?	39/92	?	?	100/76	0/24	?	2.6/3.3	?	?	8/11		?	?	0
Carp & Kornblith	G 5% E 95%	75	?	?	84	16	?	2.7	1.3	?	30		2.7	0	0
Hedberg	G	68	37	59	58	42	6	0	?	?	17	5	2.4	0	0
Jones, J. C. (1942)	G	36	?	?	100	0	0	0	0	0	55	0	0	0	0
Olive View Sanatorium series collected by Goorwitch	G 55% E 45%	365	?	?	66	31	3	6	4	3	7	7	2	0	2
Dickey	−	139	−	−	−	−	−	−	−	−	−	−	3.6	−	−
Goorwitch (1943)	G	48	23	77	75	25	1.8	1.8	0	0	5.5	3.6	0	0	0
Total (Goorwitch's collected series), 1944 (1933-1943)	G 41% E 26% C 3% M 30%	5,114	33	61	83.5	16	3.3	1.7	2.3	2.5	16	9.5	3	0.24	1

XII—CONT'D

MIXED TUBERCULOUS	LOSS OF PNEUMOTHORAX SPACE	DEATH	OPERATIVE RESULTS (%) CAVITY: CLOSED	CAVITY: PATENT	SPUTUM: CONVERTED TO NEGATIVE	SPUTUM: UNCONVERTED	PNEUMONOLYSIS: COMPLETE	PNEUMONOLYSIS: INCOMPLETE	TECHNICALLY: SUCCESSFUL	TECHNICALLY: UNSUCCESSFUL	CLINICALLY: SUCCESSFUL	CLINICALLY: UNSUCCESSFUL	MISCELLANEOUS
?	?	4	?	?	?	?	?	?	?	?	80	20	
0	1.3	0	72	28	?	?	?	?	74	26	79	21	Average preoperative age pneumothorax 6 mo.; complete absence of complications 80%; no pleurocutaneous fistula or extension of T.b.
?	?	3.3	87	13	?	?	?	?	88	12	76	24	Average preoperative age pneumothorax 4 mo.; contralateral source T.b. 32%; operative time few to 90 min.
?	?	5	?	?	?	?	?	?	84	16	79	21	No pleurocutaneous fistula
0	0	0	?	?	85	15	81	19	–	–	88	12	P.O. period of observation for complications only; no embolism or shock or pleurocutaneous fistula
5	?	0	53	47	54	46	?	?	?	?	54	46	Contralateral source of T.b. 47%; no shock
?	?	0.5	75	25	?	?	?	?	?	?	?	?	
0	?	0.5	90	10	87	13	?	?	96	4	96	4	Preoperative age pneumothorax 1½-2 mo.; average operative time 60 min.; secondary perforation 0.5%; complete absence of complications 71%
?	?	1.4	?	?	75	25	?	?	81	19	?	?	
2	?	2	?	?	?	?	?	?	?	?	?	?	Average operative time 60 min.
0	0	0.8	69	31	43	57	?	?	?	?	?	?	Preoperative age of pneumothorax 1-8 mo.; contralateral source T.b. 13%; no extension of T.b. or pleurocutaneous fistula
0	?	0 1.1	?	?	90 71	10 29	?	?	?	?	?	?	Average preoperative age pneumothorax $\frac{1\frac{1}{2}}{6}$ mo.; complete absence complications $\frac{82\%}{75\%}$
0	?	4	44	56	41	59	43	57	–	–	40	60	Contralateral source T.b. 83%; complete absence complications 27%; extension of T.b. 4%; no pleurocutaneous fistula
0	?	0	86	14	87	13	?	?	?	?	93	7	Preoperative age of pneumothorax 1½-2 mo.; contralateral source T.b. 13%
0	0	0	?	?	94	6	50	50	–	–	94	6	Contralateral source T.b. 35%; no nerve injury or pleurocutaneous fistula
2	?	3	?	?	?	?	30	70	–	–	?	?	Average preoperative age pneumothorax 9 mo.; average operative time 65 min.; complete absence complications 34%; extension T.b. 2%; no air embolism
–	–	–	–	–	–	–	–	–	–	–	–	–	From a paper on T.b. Empyema
0	0	0	76	24	76	24	55	45	–	–	?	?	Average preoperative age pneumothorax 8 mo.; contralateral source T.b. 23+%; average operative time 60 min.; complete absence complications 56%; no extension T.b., shock, nerve injury, air embolism or secondary perforation
1	3	1.18	72	28	73	27	52	48	90	10	73	27	Operative stages 5,886; date of operations 1927-1942; duration of P.O. observation 1-60 mo.; minimal T.b. 6%; prolonged fever 7%; severe subcutaneous emphysema 2.6%; obliterative pleuritis 7%

title given this section of the manuscript. The postoperative clinical results of pneumothorax in my own series will be presented under the headings of Cavity Status and Sputum Status.

In the absence of restricting adhesions we regard a clinically unsuccessful pneumothorax as a failure due to factors other than mechanically ineffective collapse. Why blame the operation when, in the absence of postoperative complications, pneumothorax remains a clinical failure despite conversion by means of complete pneumonolysis from mechanically defective into mechanically perfect collapse? It is of the pneumothorax that we expect cavity closure and sputum conversion. All pneumonolysis should be expected to achieve is concentrically free collapse which is our aim when pneumothorax is first induced. That if pneumothorax is indicated at all it should be free of restricting adhesions is concluded on the basis of past experience of those who observed that superior results, both immediate and ultimate, were obtained in patients with concentrically free collapse either spontaneous or brought about by pneumonolysis.[24, 31, 33, 43, 44]

I believe it unfair to the procedure of pneumonolysis to judge it by the subsequent clinical results of pneumothorax or to compare it to phrenic nerve interruption. It is true that in the presence of pneumothorax neither a technically successful phrenic nerve interruption resulting in paralysis and elevation of the hemidiaphragm nor a complete pneumonolysis resulting in concentrically free collapse is synonymous with clinical success of the pneumothorax, but this is as far as the similarity of the two operative procedures goes. Phrenic nerve interruption is not a substitute for pneumonolysis. Close analysis reveals that phrenic nerve interruption does not alter the character of pneumothorax restricted by adhesions and is an independent procedure apart from pneumothorax and therefore entitled to its share of credit or blame for clinical results. Complete pneumonolysis, on the other hand, radically alters the character of the collapse by pneumothorax and as an integral part of collapse by pneumothorax is not entitled to its own clinical results; the clinical results of collapse are those of pneumothorax and not of pneumonolysis. The results of pneumonolysis consist of mechanical alterations in collapse and of operative and postoperative complications.

Cavity Status.—In my collected series cavity status following pneumonolysis was found reported for about one-half of the patients and cavity closure ranged from 44 to 90 per cent and averaged 72 per cent. In my own series of 50 lungs there were 11 lungs with no preoperative x-ray evidence of cavitation, 1 lung with insufficient x-ray follow-up, and 4 with definitely insufficient operative freeing of the lung (done early in my experience) to expect any alteration in the character of the collapse. In the remaining 34 lungs cavity closure was obtained in 74 per cent and some or all of the cavities persisted in 26 per cent.

Insofar as pulmonary cavitation is concerned, the aim of the operation is to alter the collapse to bring about cavity closure as speedily as possible. In my series the first roentgenogram was made one week postoperatively in the great majority of cases; in a few it was made within the first three postoperative days, and in several one to three months postoperatively. Subsequently patients were x-rayed at two- to three-month intervals. It was therefore impossible to establish accurately the actual interval between operation and cavity closure. However, with the data in hand an attempt was made to determine the cavity status in the first postoperative roentgenogram as well as in the latest, and to establish the date of cavity closure. Thus, in the first postoperative roentgenogram of the 34 lungs all cavities were closed in 18, or 53 per cent, some of the cavities closed in 3, and all cavities persisted, although smaller, in 13. In the final roentgenograms the findings were: 25, or 74 per cent, 2 and 7, respectively. Earliest x-ray evidence of cavity closure was found in four days to seven months and an average of 1.7 months postoperatively; no relationship was noted between the type of operation and the time of closure. Carp and Kornblith[5] reported cavity closure in an average of about one month following complete, and two months following partial, pneumonolysis. Some of the lungs in my series were subsequently re-expanded and again collapsed by thoracoplasty and in these cavity status was given as of the date of discontinuance of pneumothorax.

Sputum Status.—In my collected series sputum status following operation was found reported for about one-half of the patients and sputum conversion ranged from 41 to 95 per cent and averaged 73 per cent. In my own series of 48 patients there were 12 whose sputum was negative preoperatively, 12 with demonstrable sources of positive sputum other than cavitation in the homolateral lung (contralateral cavitation, laryngeal and/or trachebronchial ulceration), and 3 with definitely insufficient operative freeing of the lung (done early in my experience) to expect any alteration in the character of the collapse. In the remaining 21 patients, 7 of whom had no x-ray evidence of cavitation, the sputum was positive in 14 on concentration and in 7 on culture only. Sputum conversion was achieved in 76 per cent of these and it failed in 24 per cent.

One of the chief aims of early pneumonolysis is to alter the character of the collapse to produce sputum conversion as speedily as possible after induction of pneumothorax. In my own small series sputum studies were not made at regular postoperative intervals; it is therefore impossible to establish accurately the earliest date of sputum conversion. The date of the first negative sputum followed by consistently negative sputa was regarded as the date of conversion. During the first postoperative month no sputum examination was done in 9 patients, the sputum remained positive in 5, and it was negative in 7 pa-

tients. At the time of discharge or in April, 1943, the sputum was converted in 16, or 76 per cent, patients and unconverted in the remaining 5, or 24 per cent. Of the 5 remaining positive, 3 were positive on concentration and 2 on culture only. Of the 16 in which it was converted, 14 were on the basis of an average of 2 cultures of sputum and/or gastric washings and the remaining 2 on the basis of an average of 4 examinations by the concentration method only.

In my series conversion took place one to seven months and an average of three months postoperatively; in 10, or 63 per cent, it was converted in three months or less and in the remaining 6 in over three months. Without stating their criteria of sputum conversion, Stemmerman and Tchertkoff[44] reported 88 per cent sputum conversion within the first three postoperative months and 12 per cent after this time; Carp and Kornblith[5] reported sputum conversion usually one month following cavity closure and an average of two months postoperatively in complete and three months in partial operation. Employing rigid criteria Jones[29] reported an average of five and one-half months for sputum conversion.

DISCUSSION

Like any other therapeutic procedure, closed intrapleural pneumonolysis should be evaluated by the positive benefit to the patient and by the absence of complications aggravating the patient's condition which the operation was intended to improve. It is realized that in especially desperate circumstances pneumonolysis may be the only procedure offering any hope at all.

Examination of data in Table X will disclose that while some of the series reviewed were remarkably free of serious complications, the incidence for the entire collected series based on complications reported definitely as present or absent was not very low. If failure to mention a particular complication were regarded as its absence, the incidence of complications for the entire collected series would have been lower than that given in Table X. When it is remembered that pneumonolysis is an elective procedure and only rarely one of emergency, it will be realized that there is definite room for reduction in the incidence of the more serious complications. As already pointed out by Newton,[34] the incidence of these complications can be reduced to the minimum by improvement in both operative technique itself and surgical judgment as to operability of thoracoscopically inspected adhesions. Freeing or releasing of adhesions off their parietal attachments as contrasted with cutting, dividing, and severing them would go a long way in preventing serious lung injury.

While none of the postoperative complications in my own series, except for the single instance of intrapleural hemorrhage, were of any consequence, it is of interest to know that among those febrile the incidence of exudative infiltration and pleural effusion at the time of

operation and of early, partial or prolonged operation was slightly higher than among those afebrile postoperatively. Among patients with postoperative effusion the incidence of early and partial operation was slightly greater than among those without postoperative effusion. However, the benefit derived from earlier cavity closure and sputum conversion undoubtedly more than outweighed the disadvantage of the minor complications mentioned.

In examining the procedure of pneumonolysis for any positive benefit to the patient, improvement in the mechanical character of the collapse, the only direct result of the operation, is also the only true criterion of benefit. This criterion is supported by the universally recognized observation that collapse free of restricting adhesions is in the great majority of instances synonymous with clinically successful collapse. However, it should also be mentioned that partial or incomplete pneumonolysis is often sufficient to alter the collapse so as to result in clinical success. In my collected series the incidence of clinical success is almost uniformly greater than the incidence of complete pneumonolysis.

The relationship between the type of pneumonolysis and the clinical results of pneumothorax ranged from the statement of Andrews,[3] that clinical success was only slightly more frequent following complete than incomplete operation, to the report of Edwards and Lynn,[16] who obtained successful "radiological results" following complete pneumonolysis two and one-half times as frequently as following partial operation. In attempting to find out why in 7 patients of my own series cavitation persisted despite greater incidence of complete pneumonolysis and smaller incidence of large adhesions, it was discovered that the average known age of cavitation and of pneumothorax was one and one-half times as great and incidence of obliterative pleuritis three times as great as among the 25 in whom cavity closure was achieved. Tuberculous bronchitis did not appear to be a factor in this small series.

A similar attempt to explain failure to convert sputum despite complete pneumonolysis in 5 patients free of contralateral source of positive sputum led to the discovery that the incidence of cavitation and the average known age of cavitation and of pneumothorax were twice as great as among the 16 patients in whom sputum conversion was achieved despite a lower incidence of complete pneumonolysis. Suspicious bronchoscopic findings either before or after operation were much more common among those in whom sputum was not converted than among those who succeeded. These findings indicate that better results from postpneumonolysis pneumothorax may be expected by earlier induction of pneumothorax and earlier pneumonolysis, and in patients free of such complicating factors as obliterative pleuritis and tuberculous bronchitis.

To be truly the optimum time for pneumonolysis it must be established that the technical and clinical results will be better and be obtained sooner, and the complications fewer and less serious if the operation is done at this time than if it is postponed. While there is universal agreement not to go on with a clinically unsuccessful pneumothorax indefinitely, the recommendations regarding the optimum time for pneumonolysis vary considerably. The time recommended in the literature reviewed as the optimum time for pneumonolysis ranged from three weeks to six months following induction of pneumothorax,[5, 12, 24, 29, 33, 48] the trend being definitely in the direction of earlier operation. Others reported that no relationship could be found among preoperative duration of pneumothorax, clinical results, and incidence of postoperative complications[16, 21, 44] and recommended handling each case on its own merits, that is, individualizing.[44]

In his collected series, Moore[33] did not state the preoperative duration of pneumothorax; however, he did recommend three to six months of collapse prior to consideration of pneumonolysis for two reasons: to allow for adhesion stretching and possible cavity closure and to render the pleura less irritable and less likely to react to operative trauma. In discussing Moore's paper in 1933, O'Brien recommended giving pneumothorax at least six months before pneumonolysis is attempted because before that time one cannot tell whether or not cavity will close without pneumonolysis.[33] In discussing Drash's paper in 1938 both Jacobeus and Welles argued that operating within two months of the induction of pneumothorax did not lead to inferior results or increased incidence of complications and that adhesions grew more fibrous, thicker, and shorter with time.[12]

In my own small series here reported serious complications were not encountered, but it was found that failure to obtain cavity closure and/or sputum conversion was definitely associated with pneumothorax of duration one and one-half to two times longer than that associated with clinical success. I agree with those who advocate early thoracoscopy without waiting six months to see whether the adhesions will stretch and the cavity close, provided the pneumothorax space is large enough to make operation feasible.

According to Moore[33] the indication for pneumonolysis is incomplete pneumothorax of three to six months' duration which on account of string, cord, or band adhesions has not produced a satisfactory collapse of diseased lung, that is, cavity closure, sputum conversion, and freedom from distressing cough and pain after refills. The discussants of his paper declared that the presence of patent cavities and adhesions in the roentgenograms did not necessarily mean that the adhesions were holding the cavities open; phrenic paralysis and increased intrapleural pressures were advocated before attempting pneumonolysis because stretching adhesions was not very dangerous and one could not tell

during the first six months whether or not cavities would close without pneumonolysis.[33] We still do not know which cavities are held open by the adhesions. But we do know that following release of adhesions the great majority of cavities do close, which suggests that they were prevented from closing by restricting adhesions. And because we do not know which cavities are and which are not held open by the adhesions and because we do know that superior results and fewer complications are obtained in the absence of adhesions, it is believed that the patient deserves a thoracoscopic examination and if the adhesions are found feasible pneumonolysis should be performed. Apparently it was this concept evolved during the past decade that was responsible for the gradual but steady liberalization of the indications for pneumonolysis, first through earlier operative intervention in clinically unsatisfactory pneumothorax[5, 12, 16, 21, 24, 29, 44, 48] and later through intervention even in symptom-free patients provided the operation can be done safely and without obvious risks.[12, 21, 23, 24, 29, 31, 34, 43, 44, 48]

SUMMARY AND CONCLUSIONS

The available English and American literature on closed intrapleural pneumonolysis published since the publication of Moore's comprehensive report in 1934 was analyzed and important data tabulated (Tables X, XI, XII). My own experience with a series of 55 operative stages on 48 consecutive and unselected patients was presented (Table IX). This small series together with those found in the literature reviewed, excluding Moore's collected series of 2,043 cases, totaled more than 5,886 operative stages on 5,114 patients.

Operative technique, complications attributable to the operation, technical results of the operation, and clinical results of pneumothorax following operation constitute the chief subject of this study. The consensus appears to be that the two-cannula technique is superior to the single cannula technique and although electrosurgery has gained considerably in popularity during the past decade, galvanocautery and the combination of the two has as many or more adherents than electrosurgery.

Criteria for attributability of complications to the operation were formulated and all such complications analyzed. It was from a preliminary study of my own small series that the impression was gained that the very great majority of postoperative complications attributable to the operation occurred within the first four postoperative weeks, as was verified in a subsequent study.[21] The more serious complications which must share in the responsibility for the slow acceptance of the operation are trauma and infection leading to massive hemorrhage and/or bronchopleural fistula and mixed infection empyema, the chief contributors to death attributable to the operation.

In speaking of technical results of pneumonolysis, the advantages of the terms complete and partial over the terms technically successful and unsuccessful must be pointed out; the former are more descriptive and tell exactly what was accomplished, whereas the latter are open to various interpretations. The clinical results of pneumonolysis, a very popular expression in the literature, should be regarded as a misnomer because the only direct results of pneumonolysis are the complications attributable to the operation and the mechanical alterations in the character of the collapse; the clinical results are those of pneumothorax and not of pneumonolysis.

Standardization of terminology is urged so that comparison of results may be more meaningful; sputum conversion statistics following pneumonolysis, for example, mean little unless it is known that a contralateral or extrapulmonary source of positive sputum does not exist. Just as important are the time interval between operation and evaluation of results and the criteria of sputum conversion. It is probable that few sanatoriums were as particular regarding the last mentioned as those of Barlow[29] and Pottenger.[38] However, this circumstance probably does not detract from the value of the data gathered because in the majority of the reports the criteria were probably uniformly less exacting than those in the sanatoriums mentioned.

A gradual and steady trend toward both earlier pneumonolysis and broadening of the indications for the operation was noted in the literature reviewed. This changing attitude must be attributed to the recognized superiority of clinical results and lower incidence of complications in pneumothoraces initially free or surgically freed of restricting adhesions. If pneumothorax is at all indicated, a concentrically free collapse should be our aim and if restricting adhesions are present and thoracoscopy demonstrates that they can be released without risking severe complications pneumonolysis is indicated.

Only thoracoscopic examination can determine the character and feasibility of the adhesions and often it only can answer the question whether or not adhesions are present. Indications for thoracoscopy and consideration of pneumonolysis that I advocate are: (1) x-ray evidence of adhesions which are not obviously diffuse and (2) a persistently positive sputum with or without cavitation despite absence of x-ray evidence of adhesions.

The optimum time for thoracoscopy is one to two months following induction of pneumothorax provided the pneumothorax space is large enough to allow instrument manipulation. Adhesions found attached to the diseased lobe should be released if this can be done safely and without obvious risks. Only in specially desperate circumstances where no other collapse procedure is feasible is one justified in undertaking a pneumonolysis involving obvious risks of serious postoperative complications. Adhesions in the presence of patent cavitation or positive sputum arising in the parenchyma of the collapsed lung constitute a

more urgent indication for pneumonolysis than adhesions over a controlled lesion in the symptom-free patient. The only contraindications to pneumonolysis are: mixed tuberculous empyema, acute febrile pleural effusion, serous or purulent and progressing obliterative pleuritis.

Since the publication of Moore's collected series in 1934, more than two and one-half times as many pneumonolyses were reported as during the preceding decade. Despite this increasing employment of the procedure in the improvement of induced pneumothorax, it must be admitted that thirty years after the introduction of closed pneumonolysis its acceptance by the profession is still incomplete. There still remain sanatoriums in which pneumothorax, phrenic nerve interruption, and thoracoplasty are performed regularly but no pneumonolysis. As long as pneumothorax retains its role of the most commonly practiced collapse procedure, thoracoscopy and pneumonolysis must be accepted as integral parts of such a collapse program both in order to improve the character of the collapse in those in whom it should be maintained and to eliminate those in whom pneumothorax is useless or even dangerous and in whom it should be abandoned in favor of a more effective procedure.

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SURGICAL MANAGEMENT OF RESIDUAL TUBERCULOUS CAVITIES FOLLOWING PRIMARY THORACOPLASTY

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IN THE treatment of pulmonary tuberculosis modern extrapleural thoracoplasty has no counterpart in properly selected cases. Throughout the past years there has been a progressive improvement in the selection of cases, in the surgical technique, and in the postoperative care and management, yet after the most exacting attention to detail in each of these departments, there remain a few cases in which a complete closure of the cavity has not been realized and the sputum continues to show the presence of tubercle bacilli. This is a problem that confronts any of us who are engaged in the surgical treatment of pulmonary tuberculosis. Alexander,[1] in the report of his results from secondary thoracoplasty, stated that 21.4 per cent of 14 patients still have positive sputum. Dolley, Jones, and Paxton[7] found 396 out of 1,636 cases with positive sputum due to incomplete approximation of cavity walls and active bronchial or tracheal ulceration. Recently O'Brien and his associates,[20] in reviewing 511 cases, stated that 12.98 per cent did not have cavities closed after operation.

Assuming that the surgical collapse is otherwise adequate as a result of the resection of the transverse processes, and sufficient lengths of the anterior portions of the ribs, the principal remaining procedure thus far accepted and generally recommended is the secondary or revision thoracoplasty, unless one of the less widely used procedures, to be discussed later, are undertaken.

The rate of incidence of this secondary operation can be reduced in several ways:

1. The resection of the transverse spinal processes and sufficient lengths of the necessary number of ribs at the time of the first series of operations
2. Judicious application of formalin to the periosteal beds at the time of the first stage
3. Elimination of undue delays between stages
4. The performance of an apicolysis (Semb procedure)[24]
5. Maintenance of an adequate period (seven months or more) of strict bed rest following the completion of the surgical program

Failure to resect the transverse processes (Fig. 1) contributes to the maintenance of the posterior vertebral gutter area into which cavities

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can "migrate" and thus minimize, in part at least, the effect of the surgical collapse. Similarly, too long anterior rib (Fig. 2) segments will prevent an adequate collapse of the underlying diseased lung tissue. Particularly is this true in the case of giant cavities and large underlying empyema spaces. In this clinic, it is the practice to resect all transverse processes, all of the first and second ribs, and generally

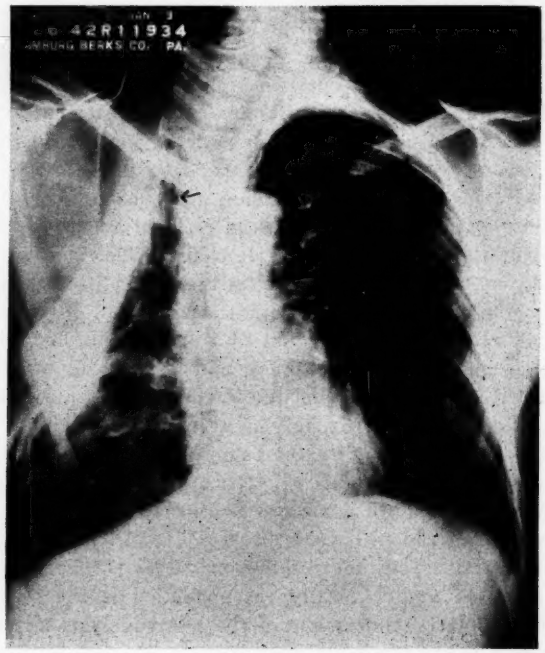


Fig. 1.—Tuberculous cavity still patent; inadequate resection of transverse processes.

all of rib three. Other ribs are resected as far anteriorly as each individual case demands. Long anterior segments are generally not permitted to remain. This practice has all but eliminated the anterolateral operation, but has not lowered our estimation of it as a valuable procedure when it does become indicated. It is, however, felt that the efficiency of the collapse is considerably enhanced by resecting the maximum rib lengths at the primary operation if by so doing there is no increase in the danger of postoperative complications.

Since the practice of applying 10 per cent formalin to the periosteal beds of the first three ribs, there has been little or no difficulty encountered as a result of reasonably prolonged periods of delay between the first and the subsequent stages. This is not true if undue delays occur, such as between the second and third stages. If such delays do occur, re-formed bone will have developed and must be removed if an

effective surgical collapse is to be realized. The average optimum mean period between stages is estimated at about three weeks (twenty-one days).

The Semb procedure either as originally described,[24] or as described by Overholt[21, 22] has been essentially abandoned because of undue complications following this modification of the regular thoracoplasty procedure. These complications have been described previously.[11, 12, 16] I still feel that the violation of the integrity of the mediastinal lymphatics accounts in a large part for the undue rise in deep wound infections and that the Semb procedure, although of particular value in

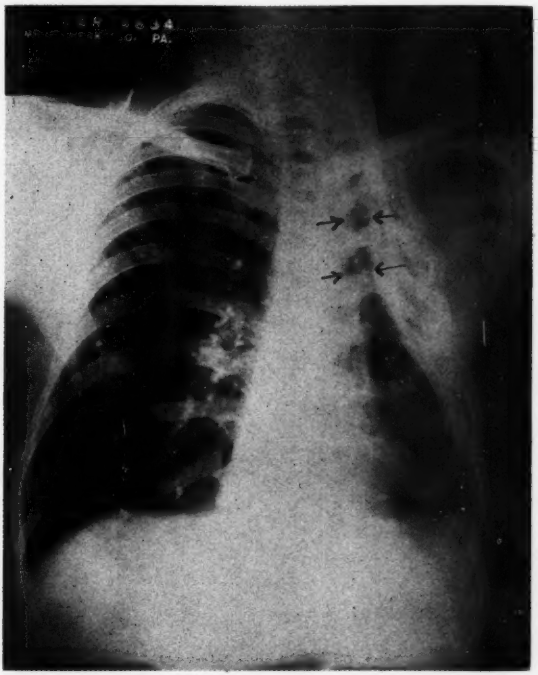


Fig. 2.—Inadequate resection of transverse processes and too long anterior rib stumps. Large cavity remains incompletely collapsed.

the closure of large and giant upper lung cavities, cannot be safely employed in these cases because of the possibility of disruption of an indispensable peripheral blood supply to the cavity wall. It is quite possible that certain of the large upper lobe cavities that remain partially uncollapsed following the usual thoracoplasty procedures (Figs. 3 and 4) would close if an extrapleural apicolysis had been performed, but I am not yet wholly convinced that the dangers do not outweigh the advantages in this type of case (Fig. 5).

Maintenance of strict bed rest following completion of the surgical program is considered to be absolutely essential to the ultimate cure of the disease. Violation of that routine, among other things, will result in a higher percentage of "nonconverted sputum cases" and poor postoperative results, thus increasing the incidence of secondary operations. This latter operation will likewise frequently fail in the accomplishment of desired results if the program of strict bed rest and sanatorium regime is again violated. A minimum of seven months of such care with the use of wedge pillows, shot bags, etc., is strongly recommended.

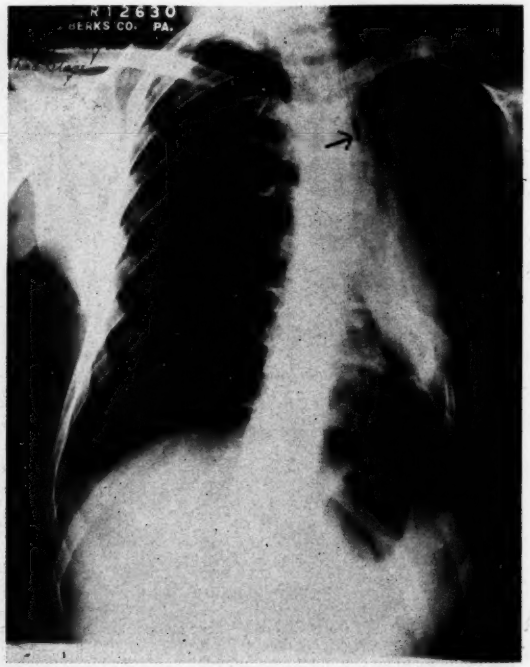


Fig. 3.—Incomplete collapse of cavity following "adequate" primary operation (thoracoplasty). Sputum is negative and patient is able to work following "mobilization and fixation" operation. (Roentgenogram of patient before "mobilization and fixation" operation.)

Early in this present series, we were confronted with the problem of a cavity which had actually ballooned out beneath the (Fig. 6) scapula and above the level of any re-formed bone (third rib periosteal bed and upward). It was for the control of this cavity that the technique hereinafter to be described was devised. In brief, this procedure consists of the mobilization of the lung and its suture or plication upon itself (Fig. 7, *A* and *B*). Since the first few cases, it has been adopted to a large extent as a part of most revision operations. Up to the

time of this report 16 patients have been subjected to the modified procedure. Good results have been realized in all instances although the number is too small to permit of definite conclusions regarding the value of this or any operative technique; however, it is felt that a very distinct advantage has been gained.

The position of the cavity, the character of the cavity wall, and the presence or absence of an increased intracavitory pressure are considered to be important factors militating for or against the success of a well-performed primary operation. Of these factors the position of the cavity in the anteroposterior plane has heretofore been least discussed.

Fig. 4.—Residual cavity following primary thoracoplasty. Cavity is closed and sputum is negative following lung mobilization and fixation.

It has been observed that the greater majority of tuberculosis cavities (Fig. 10, *A* and *B*) when viewed on the roentgenogram following a lateral projection are situated posteriorly. This peculiarity explains for us one of the reasons why obliteration of the posterior vertebral gutter must be accomplished and maintained if the complete collapse and closure of many pulmonary excavations is to be realized. By the same token, it seems to explain why certain cavities persist in remain-

ing patent not only following the primary but likewise following some secondary operations. It was reasoned, therefore, that if this anatomic situation could be altered these refractory cases could be effectively controlled and the dangers attendant upon the Semb procedure, and others, eliminated. The technical problem did not present any unusual difficulties although certain cautions had to be observed. These will be

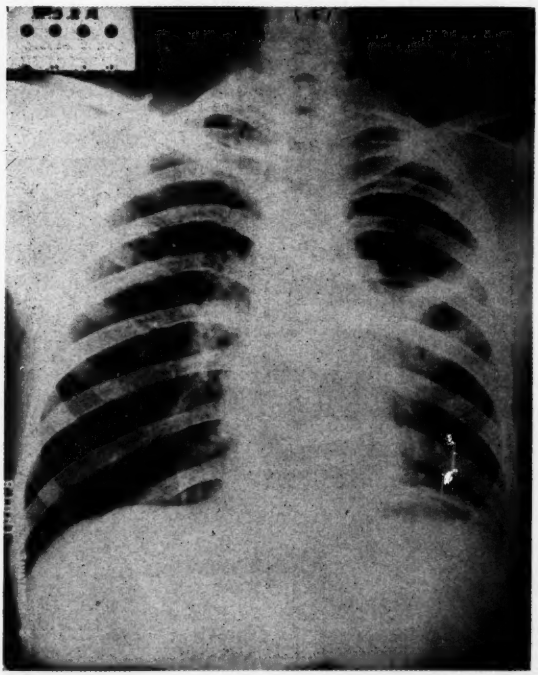


Fig. 5.—Multiple and multilocular cavitation of upper two-thirds of left lung; entire upper lobe excavated. Apicolysis is considered dangerous in this type of case.

described later in this communication. The maneuver was carried out somewhat timidly at first, but is now considered to be well established without having incurred troublesome complications, and with sufficiently encouraging results to warrant its continuance in our clinic.

Although this apparently new maneuver has aided tremendously in reducing our percentage of "nonconverted sputum cases" we always attempt to carry out the primary series of operations in such a way that a maximum mechanical collapse is realized. If then, cavity closure is not accomplished (Figs. 1 to 5) a secondary operation (revision) is undertaken and "mobilization and fixation" maneuver incorporated completely or partially in the majority of cases.

Before proceeding to a consideration of the technique, a short review of the salient anatomic features and their significance seems worth while.

Anatomy.—It is superfluous to describe all anatomic structures and relationships associated with the area involved in the operative field under consideration; however, certain anatomic features will bear special consideration. These include the external and internal intercostal muscles and some of the structures that are in relation with the bodies of the vertebra.

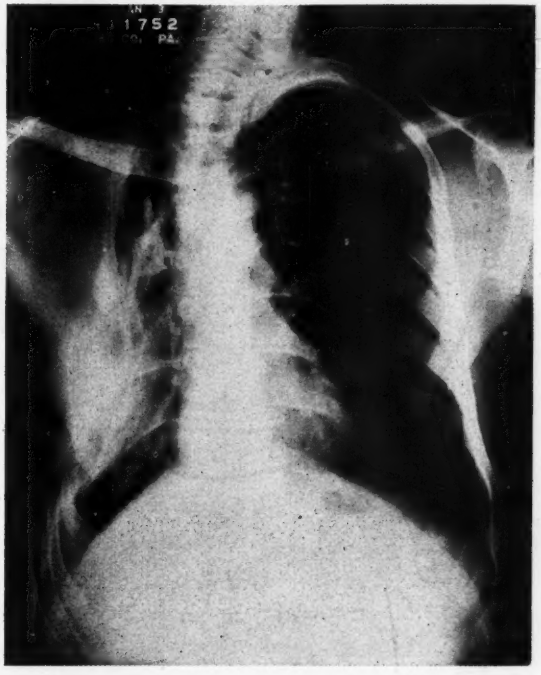


Fig. 6.—Showing the ballooning out of a large cavity after completion of a primary thoracoplasty. Complete closure and negative sputum resulted immediately after mobilization and fixation.

The external intercostal muscles have their origin at the costal tubercle posteriorly and continue anteriorly to the costochondral junction from whence they are continued to the sternum as the anterior intercostal membrane. The internal intercostal muscles, in contrast, continue from the sternum to the angles of the ribs as muscles, but from the angles of the ribs backward to the vertebra are continued as the intercostal membrane.

The intercostal vein-artery-nerve (intercostal bundle) lies between these structures and beneath the lower edge of the rib except from the

angle of the rib backward, where they lie in the middle of the intercostal space. The arteries arise directly from the thoracic aorta which lies slightly to the left of the midline of the bodies of the vertebra. The veins drain into the azygos or hemiazygos veins directly or indirectly through the highest intercostal on the right or the accessory hemiazygos on the left side.

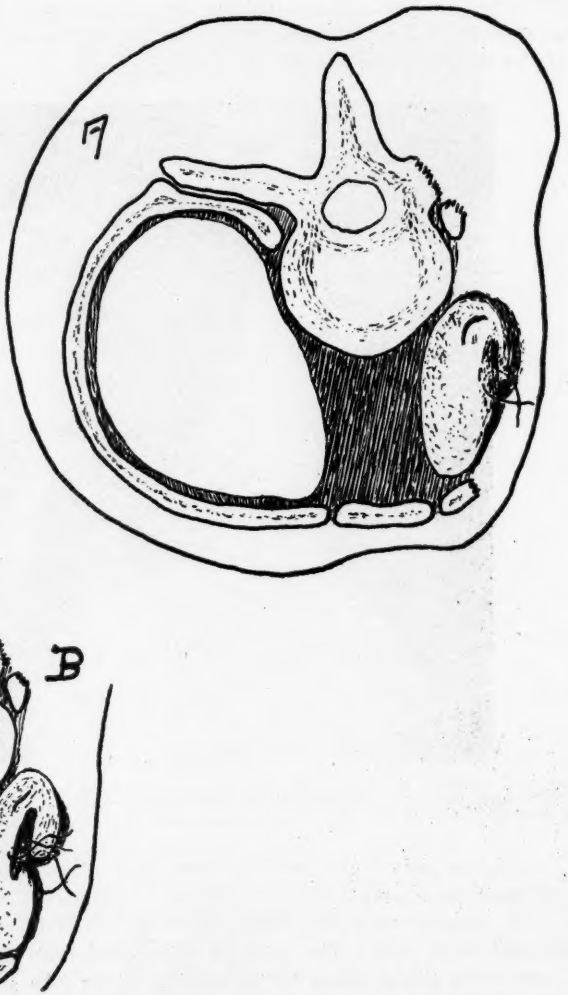


Fig. 7.—*A*, A schematic drawing showing the manner in which the lung is rolled forward and sutured (pleated) after mobilization posteriorly. *B* (insert), Suture fixation of the lung after mobilization both posteriorly and anteriorly. Anterior mobilization is more adaptable in the apical and subapical regions and in "small chested" patients.

On either lateral aspect of the vertebral bodies and ventral to the intercostal bundle lie the sympathetic chain. Coursing upward, in the midline, and lying directly upon the bodies of the vertebra is the thoracic duct.

The aorta, the esophagus, and other structures are present but as they are not too intimately related to the surgical maneuver under discussion nor subject to injury, they will not be described at this time.

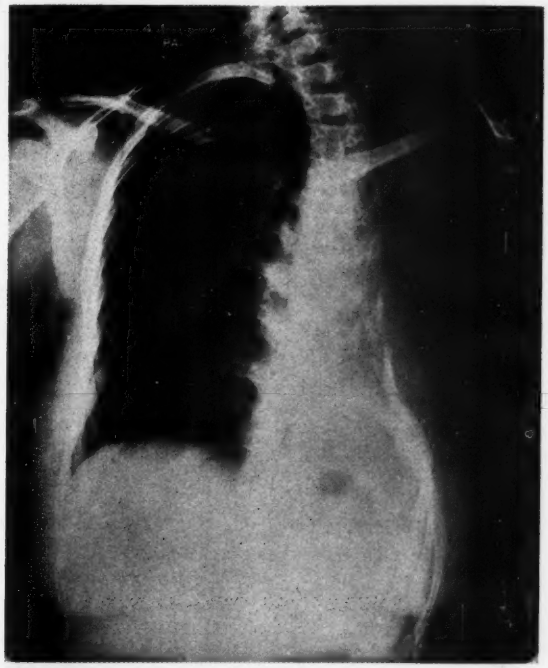


Fig. 8.—Results following lung mobilization and fixation and subtotal scapulectomy; 90 per cent of left lung originally contained multiple large cavities. Present status excellent, sputum negative eighteen months.

The significance of these features as they influence the surgical procedure is as follows: The external intercostal muscles may be divided posteriorly with complete impunity. The internal intercostal muscles do not have to be divided and if the intercostal membrane is sectioned the intercostal structures as a whole are carried along with the lung. The artery, vein, and nerve can be dissected free with ease for a considerable distance forward. Thus, collateral circulation to cavity walls will not be interrupted. Because of the overlapping and close proximity of one intercostal artery to the other, it is possible that one may be divided and yet an adequate blood supply will remain to preclude any necrosis of the cavity walls.

It is also noted that with careful dissection posteriorly there will occur no damage to the sympathetic chain although it is usually elevated and may be somewhat displaced when the whole maneuver is carried out in its entirety. Incidentally, a profound reflex response has been noted in the blood pressure (severe drop) and heart rate (marked increase, shallow volume) when the sympathetic chain is unduly manipulated. This emphasizes the need for gentle and careful handling of tissue during the dissection.

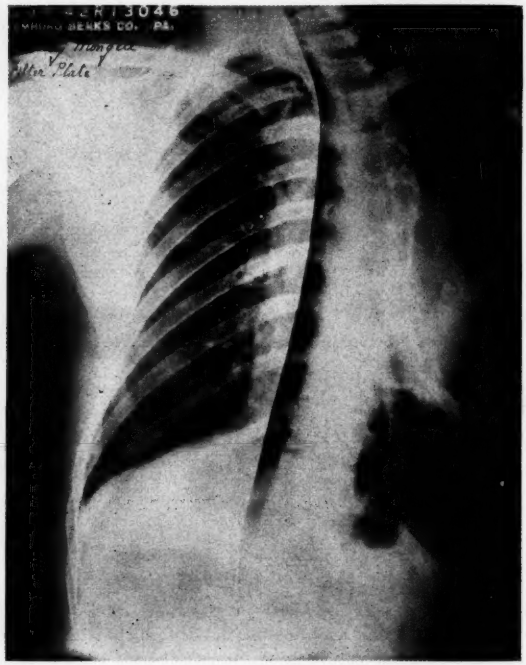


Fig. 9.—Cavity closed, sputum negative, results following lung mobilization and fixation. Same case as Fig. 3. Note area of aerated lung tissue preserved at base.

The positions of the aorta, thoracic duct, etc., are such that even with the most extreme dissection these structures will not be damaged or interfered with. Although on the left side the aorta is not infrequently palpated, with average care it is not at all subject to damage.

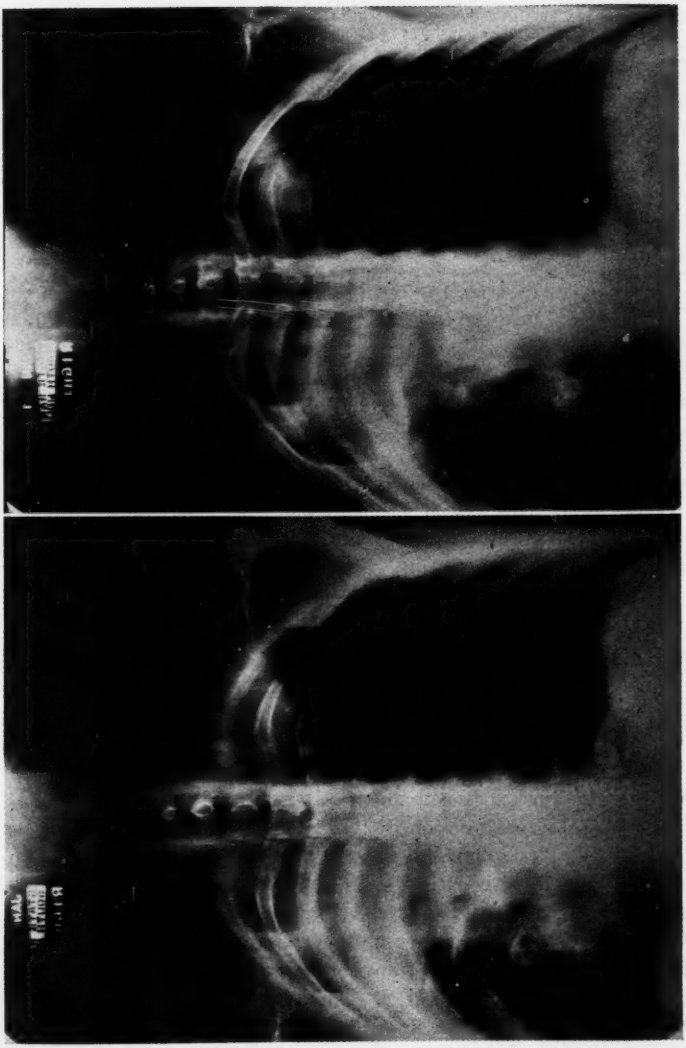
Technique.—The technique followed in removing the regenerated bone corresponds to that described by Alexander.[1] After this routine has been completed the lung is mobilized anteriorly by releasing fibrous and callous attachments around the anterior segments or sternal ends of the ribs. Portions of the anterior rib stumps are resected to whatever extent is possible or is deemed necessary for the particular case

at hand. Next, the scar tissue along the spine is incised longitudinally, following a line overlying the previous sites of the transverse processes, except the first and usually the second. The line of incision is carried deep to the bony bed that was left after the resection of the transverse processes. From this point on, blunt dissection is employed as much as possible. The greatest of care must be exercised not to injure the underlying blood vessels and lung. Thence, a free cleavage plane is easily established by dividing the loose areolar attachments—the endothoracic fascia. The plane of dissection is developed so that the lung and pleurae are elevated out of the posterior vertebral gutter and from off the lateral aspects of the vertebral bodies. If this dissection is carried out bluntly and carefully a minimum of bleeding and damage to the intercostal structures will be encountered.

The intercostal bundles, especially the vessels, are dissected forward and their posterior portions freed as far as necessary without endangering any existing collateral blood supply to underlying lung tissue or cavity wall. The lateral and anterior aspects of the vertebra are approached. Care is exercised not to damage either the sympathetic trunk, the thoracic duct, or other pertinent anatomic structures. The extent to which the lung mass is elevated from off the bodies of the vertebra is tempered by the needs of each individual case. However, in all cases where this maneuver is undertaken, the lung is always elevated from out of the vertebral gutter and from off the posterior one-half to two-thirds of the lateral aspects of the bodies of the vertebra. Posteriorly the dissection is carried upward to the second dorsal vertebra and downward to the vertebral body of the last rib resected.

The lung, thus mobilized, is then rolled forward and sutured in position from above downward (Fig. 11). The sutures, black silk and No. 2 chromic catgut doubled, are passed through the dense fibrous tissue overlying the vertebral aspect of the lung mass (posteriorly) and through the similar fibrous mass anteriorly or through the cartilaginous chondrosternal portion of the resected ribs. The sutures are tied more snugly above and less snugly below. Caution is constantly exercised so that undue constrictions will not be formed by the sutures or possibly by cicatricial bands developing at a later time. There results from this procedure a complete collapse of the posterior and lateral portion of the lung although a portion of medial and mediasternal areas may remain aerated. The wound thereafter is closed in layers in the usual manner without drainage.

Indications and Contraindications.—The indications consist principally of the same indications as for any secondary or revision thoracoplasty. That is, the closure of tuberculous pulmonary cavities that have not been closed by an adequate primary thoracoplasty in a patient who is physiologically qualified to undergo an operation of this



A. *B.*

Fig. 10.—*A*, Laminograph 4 cm. from table top shows pulmonary cavity to the best advantage. Upper lung opacity is result of postpneumothorax pleural effusion. *B*, Laminograph of same patient 6 cm. from table top. This shows cavity "fading out." Posterior position of cavity is thus demonstrated.

Fig. 11.—Photograph at completion of fixation operation. *a*, Undisturbed bony thorax; *b*, black silk and No. 2 chromic catgut sutures; *c*, tip of probe resting on body of vertebra.

magnitude. The uncollapsed cavity should be demonstrated on the routine roentgenogram or by a satisfactory bronchography.

It is absolutely contraindicated at the time of the primary operation, because of the inadvisability of passing sutures through the lung parenchyma and the limited scope of the operative field of each stage. Other contraindications include those for any thoracoplasty or any major operation. It is also inadvisable before an adequate interval of time has elapsed following the last primary thoracoplasty stage. It has been our practice not to proceed until the newly formed bone has become sufficiently well defined to render removal of it as easy as possible and further collapse of the diseased area following the primary operation. Eight to ten weeks are suggested as a minimal time limit following the last primary thoracoplasty stage. This time limit has the added advantage that the scar tissue will also have had a sufficient period of time to strengthen and develop and thus can support the heavy sutures that are to be required.

Up to the present time this procedure has not been employed in empyema cases. Complete resections of the first three ribs and long sections of the others has proved adequate to close all pure tuberculous empyema spaces and all mixed tuberculous empyema spaces usually down to the fifth or sixth rib. Below this level it has been necessary to employ the Schede procedure in the majority of cases, particularly if the empyema has existed as such for any length of time.

Pre- and Postoperative Care and Anesthesia.—Preoperative sedation is regulated according to the calculated amount of each individual patient. The average sedative, however, consists of morphine sulfate, gr. ⅙, and scopolamine hydrobromide, gr. 1/200, preceded by the intravenous administration of 1,000 c.c. of 5 per cent glucose. All patients are given postural drainage preoperatively. The anesthetic mixture is high in oxygen and the carbon dioxide absorption technique is employed, thus providing a warm moist anesthetic mixture.

Cyclopropane has been used exclusively as the anesthetic agent in all our thoracoplasty cases irrespective of the type of operation. Careful management of the depth of the anesthesia during the various phases of the operation minimizes the degree of paradoxical motion.

One factor which I consider of great importance is the patient's position on the table. Before induction the patient is placed in the desired position for operation and no marked change is permitted thereafter. Extensive manipulations of the patient after induction have often been found to lead to undesirable vascular and sometimes respiratory changes.

Immediately postoperative each patient routinely receives a 500 c.c. transfusion followed by 1,500 c.c. of 5 per cent glucose intravenously, which is administered at approximately 600 to 800 c.c. per hour. Oxygen by nasal mask is always used for a varying duration. Coughing

is encouraged and opiates are administered for the control of pain but as sparingly as possible as a precaution against depression of the cough reflex. As soon as tolerated, sandbags, shot bags, and wedge pillows are used. Posture is regulated as an additional countermeasure directed against the development of scoliosis. However, since fixation by suture of the mobilized lung in the collapsed state is the fundamental principle of this surgical procedure, it is doubted that compression measures will add much to the collapse. Nevertheless, their use is being encouraged but not urged if their application proves too painful.

Complications.—Collection of various amounts of fluid within the wound area is the only complication thus far encountered. In one case the quantity of fluid was sufficient to cause some distention of the superficial soft tissues and some pain. In this case only needle aspiration was carried out. The amount of fluid removed was just sufficient to afford relief. Fluids have all been absorbed in one to two weeks without incident. The general policy has been to permit the fluid to remain and be absorbed spontaneously. No infections have occurred.

Although no other complications so far have been encountered, it is believed that care must be exercised during the suturing and fixation of the lung to arrange the sutures so that constricting bands will not be formed, otherwise adequate drainage of the lung will be interfered with and the several sequelae of such would naturally ensue. In our series it is too soon to have discovered the full series of complications that may develop. It is, however, remarkable to note the minimum of reaction shown by these patients to the operation, even though the operations and necessary trauma and blood loss are most severe.

Advantages.—I have come to feel that this procedure, which has been termed "lung mobilization with fixation," offers definite advantages over any procedure yet suggested for the closure of these refractory cavities although this too possesses certain limitations.

The danger of wound infection and necrosis of the cavity wall is eliminated due to the fact that a sufficient amount of the peripheral vascular supply to support the life of the tissues of the cavity wall remains uninterrupted and undisturbed. The mediastinal lymphatics are not disrupted and therefore deep wound infections that apparently result therefrom have not occurred.

There is created a definite "positive or forceful collapse of the cavity" whose walls may be resistant, or the cavity may be a "positive pressure cavity," or both. In either event the factors are overcome by the counterforce exerted when the lung mass is rolled forward, sutured, and maintained in that position. The relatively permanent suturing with black silk provides a means whereby the lung is held in position out of the posterior vertebral gutter, a position more favorable for the absolute closing of cavernous lesions.

Lung mobilization and fixation represents a procedure that may be used routinely with any revision thoracoplasty without incurring any appreciable added surgical shock or postoperative complications. A second revision operation at a later date is much less likely to be needed than if this procedure was not incorporated into the usual revision operation. Lastly, but far from least, is the tremendous reduction in the degree of paradoxical motion and the possibility of a "flail chest" postoperatively, a condition feared after some of these secondary or revision operations.

RESULTS

Within the past three years (1941-1944), 203 patients have come to thoracoplasty of all types for pulmonary tuberculosis or tuberculous empyema. This represents a total of 424 stages. In addition to these 203 patients, 39 have had 45 secondary (revision) operations. Twenty-three of the 39 (or 58.1 per cent) represent the "mobilization and fixation" type of operation.

At the time of this communication the sputum of all but 1 of the 23 (or 4.3 per cent) patients is free from tubercle bacilli. A few report 1 to 2 dr. of a mucowatery sputum daily. The remainder are cough- and sputum-free. Incidentally, it has been noted that these patients upon whom the details of the operation have been rigidly carried out have an early disappearance of both cough and sputum or at least a dramatic reduction in the amount accompanied also by a change in the character of the sputum; the change being from the purulent type to the mucowatery variety.

Of the remaining 16 cases, 3 patients still show tubercle bacilli (18.7 per cent) in their sputum although there is a good mechanical collapse. Every effort has been made to discover the cause of the bacilli in these cases but so far without avail in 2 cases while in 1 there was an extensive tuberculous bronchiectasis involving the lower portions of the lung. A fourth case was positive but the patient was operated very recently and although sputum is now bacilli-free, it is too soon to justify her inclusion in this series. (This patient has likewise had a mobilization and fixation operation.)

DISCUSSION

Among the many perplexing problems in the surgical treatment of pulmonary tuberculosis there is none more discouraging than the patient who continues to have tubercle bacilli in the sputum following a technically adequate thoracoplasty with a good resultant collapse of the lung. It may have been that the cavities never completely closed or once closed have reopened even after the lapse of many months. Why these cavities reopen or fail to collapse cannot always be determined. The "heavy walled cavity" and the "positive pressure cavity" are notoriously difficult to collapse; the resistant chronic

fibrotic lung and the giant upper lobe excavations also present difficulties militating against the success of a correctly performed primary thoracoplasty.

Over a period of years a variety of recommendations and suggestions have been designed to combat this problem, yet it still remains as a challenge to the thoracic surgeon. Supplemental procedures have been designed. Semb[24] and Overholt[21, 22] suggested an apicolysis, Head[15] suggested the "myoplastic thoracoplasty," Dolley and Jones,[6, 7] Alexander,[2] and others[5] have suggested pneumonectomy and lobectomy in certain selected cases. Coryllos and Ornstein[5] have reported open drainage or cavities with pedicled muscle flaps being used to fill these cavities. I had one such successful case in a patient who died approximately two years later of bilateral renal tuberculosis. Extrapleural gauze packs, Monaldi intracavitory drainage, and the flap drainage of Rogers and his co-workers[23] are among other recommendations that have been described to aid in the collapsing of these residual excavations. Eloesser,[9, 10] quoting Adams, suggests that some method of occluding the affected lobe will be devised. It appears from the results already obtained, that lung mobilization with fixation is potentially capable of accomplishing this aim.

In developing this procedure an effort has been made to devise a method that would sacrifice as little lung tissue as possible, entail a minimum of unfavorable postoperative sequelae, and subject the patient to a convalescence no more troublesome than the average secondary operation and yet fully obtain the goal of cavity closure.

The advisability of lobectomy and pneumonectomy is open to considerable question. The infrequency of proper indications and the inevitably high mortality as yet does not justify lobectomy or pneumonectomy in the majority of cases.

Such procedures as the open drainage of cavities, by Monaldi drainage[18] or by pedicled muscle flaps, violate a long-established principle, that of incising directly into a tuberculous lung with the consequent tuberculous sinuses and fistulas. The wound infections and postoperative atelectasis that are common in apicolysis and its several variations place special limitations on this maneuver. These have been absent in our mobilization and fixation cases, without incurring undue limitations in the flexibility of the operation. So far, we have not been called upon to carry our dissections below the level of the eighth dorsal vertebra. We are therefore not able, at this time, to comment on the possible difficulties or results involving the area below this level. Above this level the area involved in the procedure is determined by roentgenogram (with or without a lipiodol bronchography). Although the entire lung above the eighth rib cannot be wholly occluded, especially in individuals with large chests, the amount occluded can be regulated almost at will so that apparently no aerated lung tissue will remain if such is desired (Figs. 8 and 9).

The series of cases upon which this report is based is yet too small to justify definite conclusions. The possibility that the series will be rapidly expanded to satisfactory proportions is remote, for in any clinic the total number of revision or secondary operations is not very great. A report at this time is therefore considered justified so that others may accord this procedure a fair trial and the accumulated results therefrom will throw greater light upon the possible value of lung mobilization and fixation.

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A PNEUMONOLYSIS SPONGE CARRIER AND DISSECTOR

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PRESENT instruments used for sponging the operative field during closed intrapleural pneumonolysis include metal applicators upon which cotton is cemented and bronchoscopic sponge carriers. Cotton applicators often foul the cannula, leave fibers of cotton within the chest, and the cotton occasionally drops off. Bronchoscopic sponge carriers are very lightly constructed and can carry only an exceedingly small sponge for intrathoracic work. They bend readily, especially when the operation proceeds to an awkward position of the chest, and do not always permit adequate pressure to be applied to bleeding points. Specially designed carriers are expensive and may break. For these reasons many operators prefer an olive tip laryngeal suction tube to keep the field clean and care little for mechanical wiping.

There are several advantages, however, in using sponges within the chest. They may be applied more gently and with better control than a suction tube, they afford traction to some degree, and are of considerable value in the enucleation of adhesions after the endothoracic fascial plane has been infiltrated with novocain solution, as originated by Ralph C. Matson, and the parietal pleura incised.[1]

For these reasons a new type of sponge carrier was developed and has been used intensively by the writer during the past year.* It consists of a 12-inch stainless steel rod, 5/32 inch in diameter with a handle having a recessed prong at its distal end. The flattened tip of the rod is 3/16 inch wide and contains a guarded prong within an elongated eye. The fabric used is gauze or bias tape ¼ inch wide.

The tape is first threaded through the eye of the carrier, then carried over the tip and pulled tightly as it is fixed on the prong at the handle. Moderate tension is all that is necessary to prevent the gauze slipping sidewise on the applicator tip. The tape is trimmed ¼ inch from the eye and the other end cut 8 or 10 inches beyond the handle. When blood has accumulated on the material at the tip the tape is merely released from the handle and drawn through the eye until a clean area appears, whereupon the tape is again fixed at the eye, trimmed, and fixed at the handle. This practice saves the time of rethreading. Time is also saved by having several of these instruments already threaded before the operation begins.

Because of temporary priority difficulties in obtaining bias tape, 1-inch gauze bandage was folded lengthwise twice by inverting the edges, and stitched slightly off center on a sewing machine. This material has no

From Glenn Dale Sanatorium, Health Department, District of Columbia.
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*May be obtained from American Cystoscope Makers, Inc., Lafayette Ave., Bronx, New York, N. Y.

ragged edges, appears to be more absorbent than commercial bias tape, and does not interfere with the rapid insertion or withdrawal of the carrier from the cannula.

The instrument can be rapidly threaded in the dark by the nurse after a little practice. There is no danger of a pledget being lost. The instrument will withstand considerable pressure to control oozing, especially when work is done under adverse conditions. In enucleation it

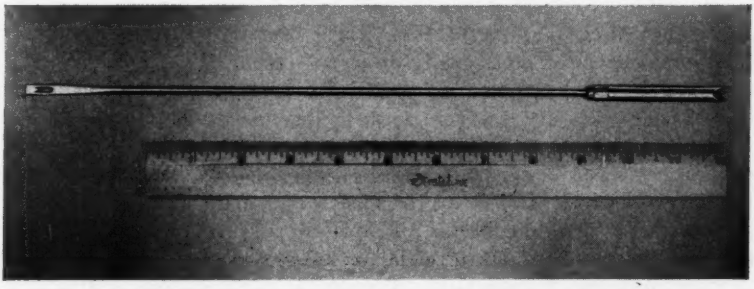

Fig. 1.

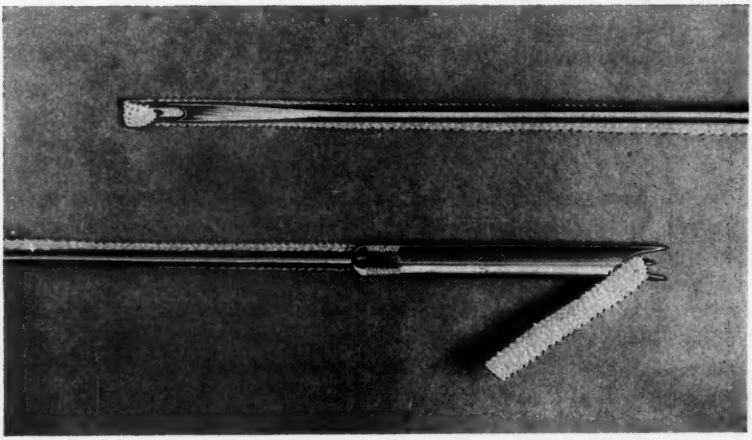

Fig. 2.

wipes the chest wall clean and does not shred fibrous tissue as does a cold cautery tip. Shredding gives rise to considerable oozing which obscures the field and frequently causes the surgeon to stop in the middle of an operation on a surface-to-surface attachment because of the fear that he may have lost the proper plane of dissection.

REFERENCES

1. Matson, Ralph C.: In Clinical Tuberculosis, by Benjamin Goldberg, Philadelphia, 1942, F. A. Davis Company.

THE AMERICAN ASSOCIATION FOR THORACIC SURGERY

Twenty-Fifth Annual Meeting

THE twenty-fifth annual meeting of The American Association for Thoracic Surgery was held in Chicago at the Drake Hotel, May 5 and 6. In the absence of the president, Dr. Edward D. Churchill, who is a Colonel in the Medical Corps, Army U. S., overseas, the office was declared vacant and Dr. Frank S. Dolley, the vice-president, was elected to fill it. Dr. Claude S. Beck was elected to the office of vice-president. Both offices were thus filled for the duration of the meeting.

Colonel William L. Keller was elected to honorary membership, honoris causa.

The resignations of: Dr. John Powers, Dr. William H. Stewart, Dr. William P. Herbert, and Dr. Edward W. Peterson were accepted with regret.

The following active members were retired at their own request to senior membership:

Dr. Carl Eggers — Dr. William H. Thearle — Dr. Carl Steinke

The following associate members were elected to active membership:

Dr. Edgar Davis
Dr. H. McLeod Riggins
Dr. Herbert C. Maier
Dr. Brian Blades
Dr. John Garlock
Dr. Frederick Kergin
Dr. Arthur M. Vineberg
Dr. Michael DeBakey
Dr. Lyman Brewer
Dr. Paul Holinger

The following candidates were elected to associate membership:

Dr. Theodore L. Badger, 264 Beacon St., Boston, Mass.
Dr. O. Theron Clagett, The Mayo Clinic, Rochester, Minn.
Dr. Frederick D. Ackerman, 1374 Sherbrooke St. W., Montreal, P. Q., Canada
Dr. Herbert D. Adams, 605 Commonwealth Ave., Boston, Mass.
Dr. Howard Thomas Barkley, 1215 Walker Ave., Houston, Texas
Dr. Joseph Gordon, N. Y., State Tuberculosis Hospital, Bay Brook, N. Y.
Dr. Archibald J. Grace, 455 Waterloo St., London, Ontario, Canada
Dr. John Benson Grow, Fitzsimons General Hospital, Denver, Colo.
Dr. Cranston William Holman, 65 East 66th St., New York, N. Y.
Dr. Julian Johnson, 3400 Spruce St., Philadelphia, Pa.
Dr. Hiram Thomas Langston, 240 East Delaware Pl., Chicago, Ill.
Dr. Robert Carlisle Major, 384 Peachtree St., N.E., Atlanta, Ga.
Dr. Ross Robertson, Muskoka Hospital, Gravenhurst, Ontario, Canada
Dr. Dudley E. Ross, 974 Dunsmuir Rd., Town of Mount Royal, P. Q., Canada
Dr. Otto C. Brantigan, 104 W. Madison St., Baltimore, Md.
Dr. Dwight E. Harken, 171 Bay State Road, Boston, Mass.
Dr. Paul V. O'Rourke, 307 David Whitney Bldg., Detroit, Mich.
Dr. J. Ross Veal, Gallinger Municipal Hospital, Washington, D. C.
Dr. David H. Waterman, 607 Medical Arts Building, Knoxville, Tenn.

The by-laws were amended to delete Sections 4 and 10 of Article VII, thus making it unnecessary for senior members to pay dues.

The deaths of six members had occurred since the last meeting in 1941. They were:

Warren G. Breidenbach
Herman Fischer
Lincoln Fisher
Maurice Berck
William Branower
H. Kennon Dunham

Dr. Richmond L. Moore was appointed chairman of the Rose Lampert Graff Prize Committee, to succeed Dr. Frank Berry, now overseas.

The following men were elected to hold office until after the next meeting:

President, Dr. Claude S. Beck, Cleveland, Ohio
Vice-President, Dr. I. A. Bigger, Richmond, Va.
Secretary, Dr. R. H. Meade, Jr., Memphis, Tenn.
Treasurer, Dr. William E. Adams, Chicago, Ill.
Editor, Dr. Evarts A. Graham, St. Louis, Mo.

The following members were elected to the council: Dr. Frank S. Dolley to succeed Dr. Frazier Gurd as the retiring president for the one-year term of office, and Dr. Alfred Blalock to succeed Dr. Frank S. Dolley for the four-year term.

The time and place of the next meeting is to be decided by the new officers and council.